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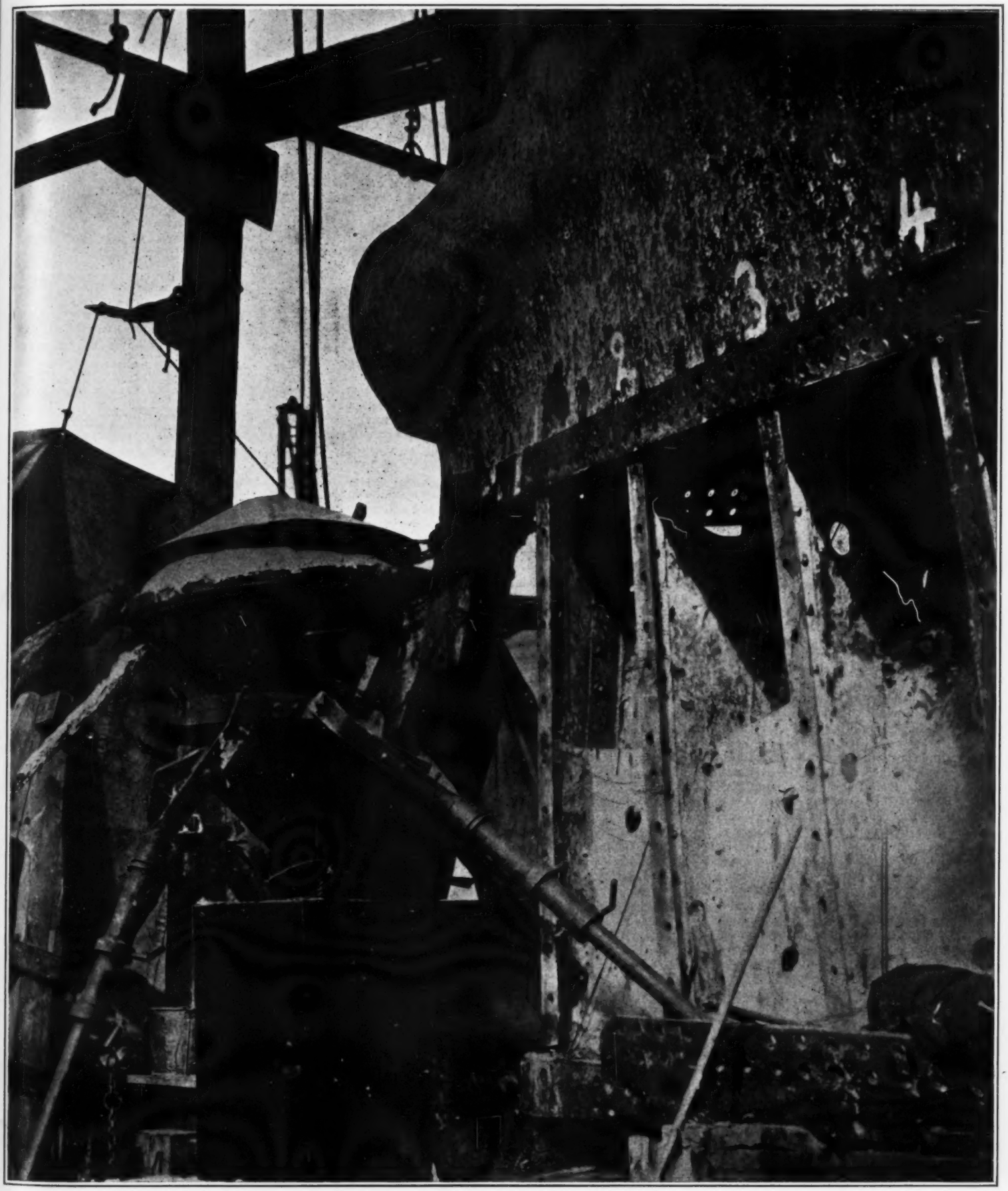

Preparing to make a thermite weld on a broken stern post.

THERMITE IN NAVAL USE.—[See page 116.]

Volcanic Dust as a Factor in the Production of Climatic Changes*

Perhaps Responsible for Profound Geological Effects

By W. J. Humphreys

GEOLOGICAL investigations have given us a great deal of information in regard to the climates of the past, and the following tentative conclusions appear to be well established: (*a*) The climatic changes were several, probably many. (*b*) They were simultaneous over the entire earth, and in the same sense. That is, colder everywhere at the same time (climatically speaking) or warmer everywhere. (*c*) They were of unequal intensity. (*d*) They probably were of irregular occurrence, and of unequal duration. (*e*) They, at least one or more, progressed with secondary variations of intensity, or with advances and retreats of the glacial edge. (*f*) They have occurred from very early, probably from the earliest, geological ages down to the present, and presumably will continue irregularly to recur for many ages yet to come.

Many efforts have been made to find a probable and at the same time an adequate physical basis for, or cause of the climatic changes that are known to have occurred; but, one after another, nearly all have been definitely and finally abandoned, either because of inconsistency with known physical laws or because they proved inadequate to meet the conditions imposed by geological investigations.

Doubtless there have been several contributing causes of climatic change, but it is the specific purpose of this paper to discuss only one of these—a cause that during historic times has often been fitfully operative, and concerning which we have much definite information.

The cause or factor in question is the presence of *volcanic dust in the upper atmosphere.*

Volcanic dust has often been mentioned as a possible cause of cold seasons. Thus in May, 1784, Benjamin Franklin (and he may not have been the first) wrote as follows:

"During several of the summer months of the year 1783, when the effects of the sun's rays to heat the earth in these northern regions should have been the greatest, there existed a constant fog over all Europe, and great part of North America. This fog was of a permanent nature; it was dry, and the rays of the sun seemed to have little effect towards dissipating it, as they easily do a moist fog, arising from water. They were indeed rendered so faint in passing through it, that, when collected in the focus of a burning-glass, they would scarcely kindle brown paper. Of course their summer effect in heating the earth was exceedingly diminished.

"Hence the surface was early frozen.

"Hence the first snows remained on it unmelted, and received continual additions.

"Hence perhaps the winter of 1783-4 was more severe than any that happened for many years.

"The cause of this universal fog is not yet ascertained. Whether it was adventitious to this earth, and merely a smoke proceeding from the consumption by fire of some of those great burning balls or globes which we happen to meet with in our course round the sun, and which are sometimes seen to kindle and be destroyed in passing our atmosphere and whose smoke might be attracted and retained by our earth; or whether it was the vast quantity of smoke, long continuing to issue during the summer from Hecla, in Iceland, and that other volcano which arose out of the sea near that island, which smoke might be spread by various winds over the northern part of the world, is yet uncertain.

"It seems, however, worth the inquiry, whether other hard winters, recorded in history, were preceded by similar permanent and widely extended summer fogs. Because, if found to be so, men might from such fogs conjecture the probability of a succeeding hard winter, and of the damage to be expected by the breaking up of frozen rivers in the spring; and take such measures as are possible and practicable, to secure themselves and effects from the mischiefs that attend the last." [1]

The idea then that volcanic dust may be an important factor in the production of climatic changes is not new, but hitherto the idea has not been supported either by a clear explanation of the process by which such dust can lower average temperatures or by a discussion of all the available observational data. In fact, the rational or theoretical discussion has not long been possible since, in almost every particular, it depends upon the results of recent investigations.

We shall now briefly consider, under separate heads, the several points essential to an understanding of how volcanic dust may influence, and of the extent to which it actually has influenced, our average temperatures—by what process it may modify and to what extent it actually has modified our climates.

Atmospheric regions.—At an elevation that in middle latitudes averages about 11 kilometers the temperature of the atmosphere becomes substantially constant, or, in general, ceases appreciably to decrease with increase of elevation; this is, therefore, the upper limit of distinct vertical convection and of cloud formation. Hence, while volcanic or other dust in the lower or cloud region of the atmosphere is quickly washed out by snow or rain, that which by any process happens to get into the upper or isothermal region must continue to drift there until gravity can bring it down to the level of passing storms. In other words, while the lower atmosphere is quickly cleared of any given supply of dust, the isothermal region retains such dust as it may have for a time that depends upon the size and density of the individual dust particles themselves, or upon the rate of fall.

Size of volcanic dust particles.—From the angular dimensions of a reddish brown corona, known as Bishop's ring, seen around the sun after the eruptions of Krakatoa, Pelé and certain other volcanoes, it has been calculated, by the aid of the laws of diffraction, that the average diameter of the particles to which this ring was due, assuming them spherical, was about 1.85 microns.[2] Hence, with this information, it becomes possible to calculate the time of fall of volcanic dust.

Time of fall.—By using the excellent measurements recently made by McKeehan[3] on the terminal velocity of falling globules, it is easy to show that spherical particles of volcanic dust of the size above determined would require more than a year to fall from only the maximum height already reached by sounding balloons down to the upper cloud limit. But as most volcanic dust does not consist of solid spheres, but rather of flakes and rods, and again, as much of it is finer than the size assumed, it follows that the time of fall may, in rare cases, be as much as two to four years, or possibly even longer. Obviously then volcanic dust once in the upper atmosphere must remain in it for many months and be drifted out, from whatever origin, into a thin veil covering perhaps the entire earth. Hence to find its effect on the temperature of the lower atmosphere it is necessary to determine its action on radiation, both terrestrial and solar.

Comparative action of volcanic dust on terrestrial and on solar radiations.—Since those volcanic dust particles that remain long suspended in the atmosphere are large in comparison to the cube of the wave-length of solar radiation, at the region of maximum intensity, and small in comparison to the cube of the wave-length of terrestrial radiation, also at the region of maximum intensity, it is easy, by the use of equations developed by Rayleigh,[4] to compare the action of the dust on the two kinds of radiation.

This calculation shows that volcanic dust particles, of the size indicated by Bishop's ring, is roughly 30 fold more effective in shutting solar radiation out than it is in holding terrestrial radiation in. Therefore a veil of volcanic dust must produce an inverse green-house effect, and, if long continued, should perceptibly lower our average temperature. Let us see then what observational evidence we have on the effect of volcanic dust on insolation intensity and average temperatures.

Pyrheliometric records.—This subject has been carefully studied by Dr. Kimball[5] of the U. S. Weather Bureau, who finds that there was a marked decrease in the insolation intensity from the latter part of 1883 (the year this kind of observation was begun) to and including 1886, from 1888 to 1892, and during 1903. There has also been a similar decrease since about the middle of 1912. Now all these decreases of insolation intensity, amounting at times to 20 per cent of the average intensity, followed violent volcanic eruptions that filled the isothermal region with a great quantity of dust.

DISCREPANCIES BETWEEN AVERAGE TEMPERATURES AND SUN-SPOT NUMBERS.

Surface temperatures.—It has been known for a long time that the number of sun-spots and the average temperature of the earth are roughly related in the sense that the greater the number of spots the lower the temperature, and the smaller the number of spots the higher the temperature. But this relation has many marked exceptions, every one of which, or at any rate all the more important ones, occurred immediately after violent volcanic explosions and presumably therefore were caused by volcanic dust.

Date.	Nature of Discrepancy.	Probable Cause.
1755–56	Cold	Kötlugia, Iceland, 1755.
1766–67	Cold	Hecla, Iceland, 1766. Mayon, Luzon, 1766.
1778–89	Warm	Maximum number (annual) of sun spots ever recorded and usually short spot period. Can it be that the solar constant actually was distinctly greater than usual at this time?
1784–85–86	Cold	ASAMA,[1] Japan, 1783. The most frightful eruption on record. Skaptar Jökull, Iceland, 1783. Vesuvius, Italy, 1785.
1799	Cold	Fuego (?), Guatemala. (Uncertain.)
1809	Cold	St. George (?), Azores, 1808. (Uncertain.) Etna (?), Sicily, 1809. (Uncertain.)
1812–13–14–15–16	Cold	Soufrière, St. Vincent, 1812. Mayon, Luzon, 1814. TOMBORO, Sumbawa, 1815, very great.
1831–32	Cold	Graham's Island, 1831. Babujan Islands, 1831. Pichincha, Ecuador, 1831.
1856–57	Cold	Cotopaxi (?), and others, 1855–56. (Uncertain.)
1872–73	Cold	Vesuvius, Italy, 1872. Merapi, Java, 1872.
1875–76	Cold	Vatna Jökull, Iceland, 1875.
1884–85–86	Cold	KRAKATOA, Straits of Sunda, 1883, greatest since 1783. Saint Augustin, Alaska, 1883. Tarawera, New Zealand, 1886.
1890–91–92	Cold	Bogoslof, Aleutian Islands, 1890. Awoe, Great Sangir, 1892.
1902–03–04	Cold	Pelé, Martinique, 1902. Santa Maria, Guatemala, 1902. Colima, Mexico, 1903.
1912–13	Cold	Katmai, Alaska, 1912.

[1] Capitals indicate exceptional violence.

The list gives the more important of these discrepancies, since the beginning of sun-spot records to the present, and their probable causes.

From the above it appears quite certain that volcanic dust can lower the average temperature of the earth by an amount that depends upon the quantity and duration of the dust, and that it repeatedly has lowered it certainly from 1 to 2 deg. Fahr. for periods of from a few months to fully three years. Hence it certainly has been a factor in determining our past climates, and presumably may often be a factor in the production of our future climates. Nor does it require any great volume of dust to produce a marked effect. Thus it can be shown by a simple calculation that less than the one thousandth part of a cubic mile of rock spread uniformly through the upper atmosphere as volcanic dust would everywhere decrease the average intensity of insolation received at the surface of the earth by at least 20 per cent and therefore would, presumably, if long continued, decrease our average temperatures by several degrees.

CONCLUSION.

It has been shown in the above, among other things, that volcanic dust in the high atmosphere decreases the intensity of solar radiation in the lower atmosphere, and therefore the average temperature of the earth, substantially as theory indicates *a priori* that it should; and this effect has been clearly traced back to 1750, or to the time of the earliest reliable records. Hence it is safe to say that such a relation between volcanic dust in the upper atmosphere and average temperatures of the lower atmosphere has always obtained, and therefore that volcanic dust must have been a factor, possibly a very important one, in the production of many, perhaps all, past climatic changes, and that through it, at least in part, the world is yet to know many another climatic change in an irregular but well-nigh endless series—usually slight though always important, but occasionally it may be, as in the past, both profound and disastrous.

An Aeroplane Ambulance.—A large biplane has been constructed by Mr. S. F. Cody at Farnborough, England, for use as a military ambulance. It will have seating accommodations for two surgeons and carry surgical apparatus, including an operating table, for use in the field.

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* Presented in substance before the Astronomical and Astrophysical Society of America, at Cleveland, O., and published in the *Journal* of the Washington Academy of Science.

[1] See Sparks, "Life of Benjamin Franklin," 6: 455-457. (Cited in *Proceedings* of the Amer. Phil. Soc., 45: 127, 1906.)

[2] I. e., thousandth of a millimeter.

[3] *Phys. Rev.*, 33: 153. 1911.

[4] *Phil. Mag.*, 47: 375. 1899.

[5] *Bull.* Mt. Weather Obsy., 3: 69. 1910.

Modern Views of Electro-Therapeutics*

Electricity Has Many Applications in Medicine

DURING the last few years our views upon the true meaning of the action of electricity upon living subjects have been growing much clearer. We begin to see the principles upon which our practice should be based, and already, as a consequence of this, our methods are changing and our results are growing more valuable from day to day.

There are two factors which have brought this about. One is the recognition of the importance of the theory of ions in all matters which concern the movement of electric currents in living tissues, and is due to the genius of Leduc, and the other is the recognition of the thermal action of high-frequency currents, an action which remained unappreciated, even if not unknown, until it was insisted on and emphasized by Nagelschmidt. It is upon these two basic facts, the chemical or ionic effects and the thermal effects of electric currents, that the electro-therapeutics of the future will be established.

First, as to the chemical aspect of the medical applications of electric currents. To begin with, all movements of current in the body, whether the currents are direct, interrupted or alternating, are ionic movements pure and simple, and their effects are due to the chemical displacements produced. We may not speak of effects which are additional to or independent of the ionic movement, for such effects do not exist. The current in the body is the double ionic movement only. The treatment by electric currents is a chemical treatment, and its chemical actions must explain the results obtained.

The stimulation of nerve and muscle is a chemical stimulation by displacement of ions. Nernst, in fact, has expressed the formula for nerve excitation in terms of ions. The sensation felt in the skin during the passage of a current is a chemical effect, and by altering the composition of the saline solution with which the electrodes are moistened, its character can be altered so that the sensory effects become more noticeable either at the negative or at the positive electrode. With sodium carbonate it is the negative electrode (ions of CO_3) which gives the greatest sensation. With sodium chloride it is the positive electrode (sodium ions), and so on in great variety.

Thus a practical lesson may at once be drawn from a knowledge of ionic effects, namely, that a solution of sodium carbonate should not be used for moistening the electrodes in electro-diagnosis, because in that procedure a small negative electrode is used with high concentration of current, and in these circumstances the presence of a carbonate in the liquid causes unnecessary pain to the patient. Again, in using chlorine ions for the softening of scar-tissue it saves the patient some discomfort and facilitates the toleration of massive currents to use the chloride of ammonium at the anode in preference to that of sodium, because the ammonium ion affects the sensory nerves of the skin in a less degree than the ion of sodium.

There is another direction in which the application of the principles of ionic movement has increased the therapeutic powers of electrical applications, and that is in the direction of treatment by larger currents. If we look in the textbooks of electro-therapeutics we see continually that currents of 5 or 10 millimeters are prescribed. Formerly that was as much as could be given without causing discomfort or producing superficial burns. The metal-plate electrodes and the small buttons or disks covered with a thin layer of chamois leather and set in handles and applied to the affected region did not permit the use of large currents; Leduc has told us why this is the case. With such electrodes the ions of hydrogen and hydroxyl which are formed at the metallic surfaces can quickly reach the skin surface. They are strongly caustic and tend to produce pain and burns, and this can be obviated by the use of electrodes composed of thick, folded cloths over which is laid a metal electrode faced with two or three layers of thick felt. The whole is moistened with appropriate saline solutions and bandaged to the patient, who thus can tolerate applications of 50 milliamperes or more, and that for times of fifteen or twenty minutes or longer without any burning or blistering of the skin.

It is not surprising that this change of method brings results which are superior to those of the past. Indeed, if the theory of ions in medical electricity had done nothing else of value, it would deserve all praise for having taught us how to use larger currents. Take, for instance, the treatment of paralyzed muscles. A distinguished French writer has recently told us that he has gradually increased the duration of his electrical applications in such conditions to periods of one hour twice daily, and uses rhythmic currents which are not less than 25 milliamperes, and that in the infantile paralysis of children the little patient is so slightly inconvenienced by these applications as to play and even to sleep while they are proceeding; also that the results of such intensive treatment are entirely good, and produce not the least sign of fatigue or exhaustion or other undesirable effects.

The ionic theory of electrical treatment which has shown us how to use large currents has also shown the necessity for them. If the results to be gained are produced by the chemical interchange set up in a tissue, it is manifest that to obtain them one must use a strength of current which is capable of producing a distinct effect; and for the same reason the time of an application must be lengthened. The chemical changes caused by a current of 50 milliamperes for twenty minutes are ten times greater than those given by 10 milliamperes for ten minutes, and are therefore ten times more likely to produce an appreciable effect. The results of adopting this view and of increasing the quantity of current employed may make all the difference between success and failure. It is thus that the treatment of neuralgias can be made effective, and the same occurs in the treatment of many affections of the joint structures.

In the ionic theory of electrical treatment we have to consider two factors, the chemical interchanges set up within the tissues and the introduction of ions from without. The second of these considerations has added notably to the scope of electrical treatment. In the treatment of superficial morbid states there can be no doubt of the actual penetration of the external ions into the part treated; and the use of the zinc ion introduced at the positive pole from material moistened with a solution of a zinc salt has led to the successful treatment by electrical means of a whole series of superficial ulcerative conditions of the skin and the various orifices of the body.

In the treatment of affections of the deeper tissues the method of the introduction of ions from pads moistened with appropriate solutions has also achieved many successes, notably in conditions of so-called neuralgia, states which are almost always due to neuritis or perineuritis, for example, in many severe neuralgias of the trigeminal nerve. Quinine and salicylic acid, the latter especially, are useful in these conditions when introduced by the electric current.

In chronic gouty conditions the introduction of the salicylic ion is also of great value. Iodine ions and lithium ions to a lesser extent also seem to be useful in gouty conditions. The chlorine ion, recommended by Leduc for its softening action upon scar-tissue, has proved itself valuable.

Leaving the chemical effects of electrical currents, let us turn to the consideration of the thermal effects. The use of electricity for thermal effects requires currents of large magnitude, and therefore requires that the ionic effects shall be reduced to a minimum. The currents of high frequency answer these requirements. With them the duration of each wave of current is so brief that the ionic movement set up is imperceptible; the displacement which the ions undergo in the very small fraction of a second for which each wave continues is minute and does not strain the elasticity of the protoplasm, if one may make use of such a phrase. On this account the currents employed may reach an ampere or more, and the usual ionic effects of currents, such as pain and muscular contraction, are absent. The thermal effects become manifest in proportion to the magnitude of the currents employed. The practical recognition of the thermal action of high-frequency currents remained long unnoticed, in spite of the great popularity enjoyed by high-frequency treatment some time ago. Somerville may be said to have awakened medical practitioners to its possible importance by his paper in 1906 on the effect of high-frequency currents in raising the surface-temperature of the body.

When we look back upon the cases which have been reported as cured by currents of high frequency we may now recognize that a large part of them can be justly attributed to thermal actions and the vasomotor effects secondary to these. The circulatory effects, the relief of various states of spasm and congestion, and of painful affections of the joints, of neuritis and neuralgia come into this category. An improvement in the lymph circulation due to the warmth would account for the results which have been obtained with high-frequency currents in certain local infections and inflammations.

In another section of high-frequency treatment, namely that of the use of the effluve or of showers of sparks in cutaneous affections, we also have to deal with thermal effects, intense but minutely localized, though it is possible that in these cases there may be another factor concerned, namely the influence of the ozone, and of the nitric acid vapors which are associated with luminous electrical discharges.

We now perceive that in high-frequency applications we have an agent for the direct warming of the tissues traversed by the current, and that the future development of high-frequency treatment will be based upon these thermal effects. The progress which has been made by Nagelschmidt and others with the large currents obtained from the modern type of high-frequency apparatus, which uses sustained oscillations, and is known under the name of diathermy, serves to emphasize this aspect of high-frequency currents. Duddell's singing arc in a modified form is used for the production of the oscillations in the diathermy apparatus.

Again, in electro-diagnosis we are on the threshold of another change. The long and patient work of many investigators upon the use of condenser discharges has begun to bear fruit, and it is clear that from the condenser we gain greater information than the induction coil and the galvanic current can give us as to the degree of abnormality in muscle in cases of paralysis, while the process of testing with condenser discharges is simpler in application and far less painful to the patient. Whereas hitherto neurologists have been content to divide muscles into two categories, those with "normal" reactions and those with a reaction of degeneration, the condenser method now permits the recognition of a considerable number of intermediate degrees. The method is based upon the observation of the minimum capacity needed to provoke the muscular contraction. As a muscle deviates from the normal standard it comes to need waves of longer and longer duration in proportion to its degree of damage, and these waves are best obtained by using a series of condensers of progressively increased capacity, charged from a constant source and discharged through the patient. Many of the muscles formerly described as normal because they had not lost the power of responding to induction-coil currents can now be seen to present different degrees of deviation from the normal, and those classed together as showing a reaction of degeneration can also be divided into distinct groups. Working with 100 volts to charge the condensers, one can use a series of ten or twelve capacities, ranging from 0.01 to 2.0 microfarads, and can find muscles showing their initial contraction at almost every step in the scale comprised within these limits.

The work of Boudet de Pâris, Hoorweg, Zanietowski, Weiss, Doumer, Cluzet, and of many other patient students of condenser discharges must be gratefully acknowledged in this connection. They have gradually brought their methods through the laboratory stages and rendered them suitable for everyday clinical work, so that electro-diagnosis in the immediate future is sure to develop in the direction of condenser discharges, and the old method with induction coil and battery current may be regarded as obsolete.

With these evidences of progress the electro-therapeutist of to-day can feel more hopeful. He is no longer tied to the old routine methods, and sees before him the commencement of a therapeutic method based upon the laws of chemistry and physics.

*Reproduced from *Nature*.

Finished thermite weld on rudder frame of torpedo boat destroyer "Paulding."

The rough casting still shows the metal left in pouring gate and riser of the mold. This metal is cut off, leaving the casting clean.

Welding rudder frame of torpedo destroyer "Dayton."

Mold box rammed up and frame being heated. The conical crucible containing the welding charge is suspended over the pouring gate of the mold.

Thermite for Naval Use

The Process is Becoming Indispensable in War and Peace

By Louis E. Browne

Until comparatively recently, if a naval vessel ran aground and fractured a steel frame or a rudder post, the ship would be dry-docked and partially taken down to replace the broken steel part with a new one. This was very expensive in both labor and material. A broken rudder frame or a cracked rib would put the ship out of commission for three or four months.

Since the perfection of the thermite process of welding steel, repairs on the framework and solid steel parts of the ship's construction, not the engines, have been made in one fifth the time and at one fifth the expense as compared with former practice. If the fifth frame from the bow snapped off in its middle, the ship is run into dry dock, her outer steel plates removed and the break repaired by the thermit process. Formerly, instead of removing only the plates, the entire frame piece would have had to be removed and the ship would need to lie in dock while the new one was being forged in the repair shops. The new process takes but about a week to fit a ship for sea while the old method requires five weeks to five months.

The process is being developed by the Navy. Its importance in time of war is readily realized when one thinks of the time it saves in repairing a disabled ship. For instance, should one of the dreadnoughts of the United States limp into port after a battle at sea with parts of her frame wrenched and broken and many of her plates bent and broken, the vessel would be dry-docked and the torn plates and those over the broken frames removed. Every broken and cracked frame could be repaired within a week or ten days. Until two years ago, when the thermit process was first extensively used by the Navy, the same work would have taken five or six months.

Mold boxes and crucibles in position for weld on U. S. S. "Nero."

Our readers will recall that thermit is a mixture of oxide of iron (or one of its allies) and finely divided aluminium metal, to which magnesium may be added to ignite the charge. The reaction, in which the oxygen is withdrawn from the iron by the aluminium, produces a very high heat.

When a ship enters dry dock with a rudder frame broken the fracture must be cleaned and prepared for the process. For instance, the U. S. S. "Penacook," shown in the picture, had a badly broken rudder post. The crack ran diagonally fore and aft and the steel was badly flaked. This necessitated the removal of about six inches of steel from the frame. This done, the ends of the two steel parts to be welded were grooved and reamed and a mold of fire clay, the size and shape of the required weld, was strapped to the stern post and rudder post of the ship.

Then a funnel-shaped crucible was bolted to the top of the mold, filled with the thermite solution, covered with a heavy cap and all was ready. After the thermite preparation had burned out and the steel cooled, the mold and funnel were removed. The picture shows the resulting weld and the cone-like piece of steel extending upward which had formed and hardened in the tube of the funnel. This cone of steel is cut off and the weld finished down to the required size and shape.

The ends of two pieces of steel to be welded together are first brought to a white heat by gas and blower. Then the thermit is fired. Within thirty seconds the action of the powder combined with the finely divided aluminium and the iron oxide has produced a heat of about 5,000 deg. Fahr. In fifteen seconds more several quarts of molten steel has run into the mold and the combustion begun to die out. This steel, which at 5,000 degrees is about twice as hot as liquid steel usually is, has acted upon the prepared ends of the broken steel frame in such a way that when the whole cools, the liquid steel has joined the parts to be welded into a homogeneous mass.

Welding the rudderpost and a break in the stern post. This view shows the pouring operation, after completion of the reaction.

A weld executed at the navy yard at Portsmouth, N. H. Repairing stern frame of the United States steamship "Penacook."

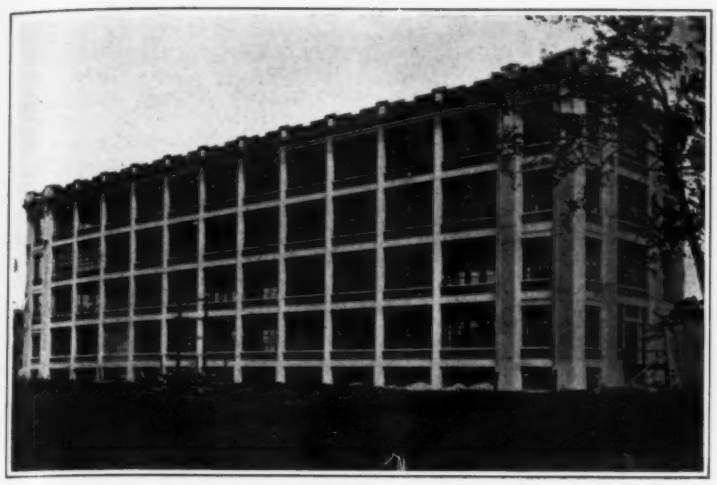


Fig. 1.—A shop with large window area.

Fig. 2.—Avoiding loss of light from belting.

Industrial Lighting*

Making the Best Possible Use of Daylight Illumination

Up to within a few years it was common to locate manufacturing plants in large cities, and often in very congested sections. This is not conducive to the securing of good daylight illumination, because even though the plant is erected in a light and open space, there is usually but little assurance that the surrounding property will remain unoccupied. In fact, the normal growth of the plant itself may make it necessary to crowd many buildings into a small space, unless a large land area is available for expansion. Hence, even when good daylight is available at the outset, the plant may be badly off for it within a few years, so that it will be necessary to run a considerable number of artificial lights during the day.

Owing to the high value of land in our large cities, shops and factories that are located there are usually constructed several stories in height; and this often means that a considerable part of the floor area receives but little daylight. In fact, when other structures are near by, it is common to find that only the extreme front and rear parts of the building are adequately provided with daylight illumination.

When it is necessary to rely upon illumination from the sides, and particularly when the building is more than one story in height, it is exceedingly important to provide a large window area, and the extreme to which this feature is pushed in many of our more recent manufacturing buildings will be evident from Figs. 1 and 2. To get the full advantage of the window surface, the height of the stories should bear a proper relation to the breadth of the building, so that light can reach the middle of the floor space without having to pass through the shop in a direction too nearly horizontal.

The interior of factories and shops should be finished in light colors, to prevent the wasteful absorption of light that occurs when dark colors are used, or when dirt and oil are allowed to accumulate upon the walls and other surfaces. The walls and roof should be kept reasonably clean, and a fresh coat of paint or of whitewash should be applied whenever they become grimy and discolored. It is very common to see the woodwork and the brick walls of a plant painted a light color, while the trusses and other structural steel parts are black, or nearly so. There appears to be no reason for painting exposed steel trusses and columns black in this way, except that it is the customary thing. We see no reason why they should not be kept white, or light colored, with as much care as the roof and walls.

Manufacturers often overlook the fact that it is important to keep the windows of their shops and factories reasonably clean, so that light can enter them freely. It is very common indeed for windows to be allowed to collect dirt until they become translucent instead of transparent, and when they are in this condition they intercept a large proportion of the light. They are often neglected, year after year; and yet it pays well to keep them washed. We recall some windows that came to our notice not long ago, on which the coating of dirt was so pronounced that it gave the impression that the panes had been painted. These particular windows certainly did not admit one tenth of the light that could have been had from them, easily, by the application of a little soap and water.

When a large amount of glass surface is used in the windows, and the admission of direct sunlight to the work is objectionable, it is well to glaze the windows with ribbed glass, which transmits the light freely, but diffuses it so that it is nowhere objectionably strong.

Prism glass can be used with advantage in many cases, particularly when the factory is surrounded by other buildings so that an almost vertical light shines down past its windows from the sky overhead, while the windows themselves are shaded in large measure by the adjoining buildings. It consists of sheets of glass that are provided with small horizontal ridges, prismatic in shape, and arranged so that when light strikes them from a nearly vertical direction, it is deflected and made to enter the shop almost horizontally.

The main objection to large window surfaces in a factory or shop is the difficulty of heating the working space during the winter months, in our northern latitudes. This objection is certainly worth consideration, but more is usually gained by providing the large lighting area than is lost through the increased difficulty of heating. In shops where small windows make it necessary to run artificial lights for a considerable fraction of the time, the cost of the auxiliary illumination so required offsets, to a certain extent, the lessened cost of heating during the cold months.

The last few years have seen a marked change in shop and factory building, in location as well as in construction. The boards of trade in the smaller cities and towns have for some time advertised the varied advantages of their respective localities as points to move industries to, or to start new ones in. Special inducements of a tangible and substantial kind are frequently offered, such as exemption from taxation for a term of years; and many of the manufacturers who have been free to do so have taken advantage of these inducements, and located in the places offering them.

With this change in location there has come a corresponding change in factory construction. As a general rule, land is plentiful and cheap in the smaller places, so that one-story buildings are prevalent there, and the problem of daylight illumination becomes reduced to its simplest terms.

Monitor roofs are often used with advantage upon one-story buildings, as they afford a convenient means of admitting light to the interior of extended spaces that would otherwise be too dark to be available for manufacturing purposes, without artificial illumination. The characteristic feature of the monitor roof is an elevated structure with glass sides, that rises, cupola-like, above the main roof, and runs along the middle of the building in such a way that the light that enters through the sides of the structure illuminates the central portions of the room below. Fig. 3 shows a modern shop that is built in accordance with this plan.

The so-called "saw-tooth" roof is another excellent device for securing good daylight illumination in one-story shops. In this construction, which is comparatively modern, the roof of the building is traversed by a number of ridges, roughly saw-toothed in shape, which are steeper on one side than on the other. They are glazed only on the steep side, and on the

* Reproduced from the *Travelers' Standard*

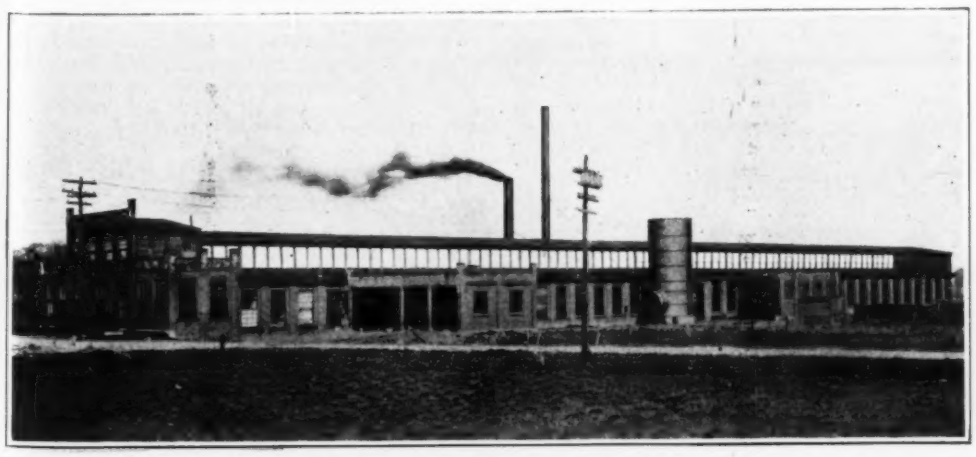


Fig. 3.—Illustrating the monitor roof.

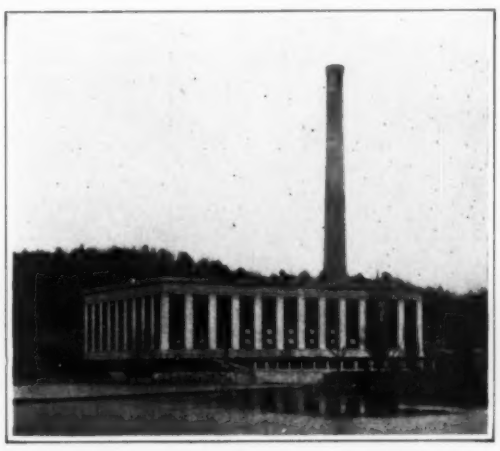


Fig. 4.—A well-lighted power house.

other they are covered with some substantial roofing material, such as slate, or tar and gravel. The saw-tooth ridges should run east and west, or nearly so, and the glazed side should face toward the north, so that the direct rays of the sun may not enter it. There is quite a marked difference of opinion among engineers as to the best slope to give the glazed sides of the saw-teeth. According to some authorities, they should make with the horizontal an angle of not less than 71 degrees in the most northern parts of the country, nor less than 77 degrees in the most southern parts; but others consider that inclination as small as 60 degrees to the horizontal can be used satisfactorily in any part of the country. It is pretty well agreed, however, that the angle at the vertex of the saw-tooth should be 90 degrees.

When conditions will permit, the building upon which the saw-tooth construction is to be used is preferably oriented so that its length extends either north and south or east and west. The saw-teeth will then run either lengthwise of the building or crosswise thereto. There is no objection, however, to running them diagonally across the roof, except that in such cases the construction work is more complicated and costly.

Saw-tooth roofs often give trouble from condensation on the glass, and also from direct leakage.

The condensation on the inner surface of the glass is sometimes exceedingly objectionable, particularly in textile mills and other plants where the dripping of water would seriously damage the product. To guard against this, the glass in the sashes is frequently made double, with an air space between. This reduces the condensation very materially, but it is not always entirely satisfactory and effective. Most roof designers prefer to have the glass single, and to run conductors or gutters along the lower edges of the windows on the inside, to receive the condensed water and lead it away into suitable drain pipes. The saw-tooth ridges, in any case, should be properly ventilated at their highest points. Condensation is materially reduced by making the sashes of wood instead of metal. Metal frames are such good conductors of heat that they greatly increase the condensation, when the weather is markedly cold.

Direct leakage is likely to occur unless the roof is carefully built, and it is most troublesome when the successive saw-tooth ridges follow one another with little or no horizontal space between. Leakage can best be avoided by leaving a flat place in the roof at such points, at least two feet wide, and attending carefully to every joint and angle. The glazing should receive special attention, because in winter the spaces between the ridges are likely to become more or less blocked with ice and snow, so that when a thaw comes the water will back up and run over into the building if there is any leaky place that it can reach. To guard against trouble of this kind the roof should be drained as thoroughly as possible, and it is best to run the drain pipes inside of the building, so that they will always be free. Pipes that run down the outside of the building will often remain open at the top, where they are close to the warm roof, and freeze up solid at some lower point, so as to become entirely useless.

It is important to locate each machine in the shop, so far as this may be practicable, in such a way that the light from the windows does not shine directly into the face of the operator.

Light from windows and roofs is often seriously obstructed by belts, in shops where these are numerous. The use of individual electric motors, one to each of the machines that are to be driven, keeps this source of trouble down to a minimum, but a great deal can be accomplished, even when electric motors are not used. Fig. 2, which is from a photograph taken a number of years ago, shows a plan that was successfully carried out in a certain textile mill, before the use of electric motors for individual drive became at all common. The machines in this picture are all belt-driven, but the shafting from which the belts come is below the floor, so that there is no obstruction of the light. (The belts and pulleys are not properly guarded in this room, and we do not recommend the arrangements that have been made for artificial lighting; but the picture shows nevertheless what can be done to prevent the belting from darkening the room.)

Good daylight illumination tends to improve shop conditions in many ways. Sanitary conditions, for example, are always better where the light is good. Tuberculosis germs, that can live for a long time in dark places, are killed in a few hours by direct sunlight, and they perish in three or four days in rooms that are well lighted by strong, diffused daylight. Good daylight also tends to maintain good spirits among the employees, and to make them more cheerful and more efficient, and thus, indirectly, tends to reduce the number of accidents that occur.

The Effect of Incombustible Dusts on the Explosion of Gases*

Evidence is Somewhat Conflicting, But Seems to Show That Such Dust Has a Quenching Effect

By Prof. H. B. Dixon, F.R.S., and Colin Campbell, M.Sc.

THE effect of incombustible dusts on the explosion of gases is of special interest at the present time by reason of the method now being extensively tried in mines for rendering coal-dust non-explosive by mixing it with incombustible dusts.

On the one hand, the opinion is held that such inert dusts as powdered shale, fuller's earth and flue-dust, act the same part, when mixed with coal-dust, as inert gases do when mixed with explosive gas mixtures; on the other hand it has been contended that the introduction of a finely divided solid into a coal mine might be dangerous owing to its action in promoting the combustion of fire-damp upon its surface, and in particular the experiments of the late Sir F. Abel have been quoted as proving that danger from such catalytic action is by no means remote.

The committee appointed by the Home Office to carry out experiments on the prevention of explosions in mines have examined this problem at their experimental station at Eskmeals both by trials in a gallery similar to that used by Abel, and also by exploding gases in tubes and bombs with and without the addition of dusts. Meanwhile we have made many laboratory experiments here to test the question whether the presence of a "catalyst," such as platinum, can induce an explosion in an otherwise non-explosive mixture of gases, and whether finely divided magnesia or shale-dust acts catalytically in propagating flame, or merely behaves as an inert substance.

According to the kinetic theory, the molecules of a gas are in a constant state of motion, coming into collision one with another and with the walls of the containing vessel. The temperature of the gas depends upon the "mean velocity" of the moving molecules. But these motions are not uniform. At any moment some molecules are moving faster and others slower than the average. Clerk Maxwell has calculated that about 2 per cent of the molecules of any gas are moving with a velocity more than twice that of the mean velocity. In an inflammable mixture of gases such as electrolytic gas there is a similar distribution of velocities, so that there are some hydrogen molecules moving more quickly than the other hydrogen molecules, and some molecules of oxygen moving more quickly than the other oxygen molecules. If chemical combination begins as a result of the collisions between two of these more rapidly moving molecules of opposite kind which are comparatively so few in number, this combination would take place here and there at infrequent intervals, and the heat generated would be dissipated among the mass of the surrounding molecules.

When such a mixture is heated up artificially more and more of the molecules will move rapidly enough to produce chemical combination on collision; and finally a state will be reached at which these collisions are sufficiently numerous to overcome the loss of heat by conduction. At this stage the mass of gas as a whole begins to self-heat, i. e., to rise in temperature owing to the chemical action independently of the external source of heat. This is the "Temperature of Ignition." If nothing interferes with the free motion of the molecules, the number of chemically effective collisions increases at an ever-increasing rate until a flame appears and spreads through the mixture. Below the "Ignition temperature" chemical combination is quite slow; above the ignition temperature combination increases in rapidity until inflammation occurs: in the flame, combination is very rapid. In flame the rapidity of chemical combination may vary greatly; in the most intense form of flame—that of the explosion-wave—the combination is almost instantaneous.

In the explosion-wave the physical pressure-wave generated by the movement of the molecules in the burning layer, is transmitted (by collisions) into the unburnt gases beyond and is continually renovated by the chemical action there set up. The average rapidity of the molecules taking part in the wave is so great that it is probable that a large percentage of the collisions between molecules of an opposite kind result in chemical combination, and the flame travels forward with the forward velocity of the molecules themselves.

In the transmission of flame through a gas mixture the most usual case is for a portion only of the gas to be ignited and for the heat so produced to raise the temperature of the contiguous portion to the ignition point, and so on layer by layer through the mixture.

But in a mixture of gases, such as methane and air, the quantity of inflammable gas present may be insufficient to allow the flame to propagate itself throughout the mixture when a portion of the gas is so raised in temperature by the introduction of a flame or spark. In the portion of gas directly heated by contact with the flame chemical union between the methane and oxygen molecules is set up, and this region of combustion is visible as a halo or "cap" round the source of heat. When a safety-lamp with lowered flame is introduced into an atmosphere in which methane or coal-gas is gradually introduced, a delicate cap shows in a cone above the flame which increases in height and intensity until it reaches the top of the lamp. As the mixture in the lamp becomes explosive the flame expands at the top and creeps down inside the lamp until the whole of the gauze is covered with flame, and the original flame over the wick goes out for lack of air. The phenomena described are well seen in the apparatus constructed by Messrs. Oldham for lamp-testing. In the same apparatus, filled with a mixture below the explosive limit, the naked flame of a taper shows a blue cap, which may be easily detached by a rapid movement of the taper. Detached caps or "flares" of flame may thus be formed which move upward and die out after a time. Similarly, when a rapid current of air containing inflammable gas is drawn past a flame in a gallery, portions of the cap on the leeward side of the flame may be detached and float away as "flares." In these caps and flares visible combustion is set up, but it dies down when separated from the original source of heat because the rate of chemical union in the dilute mixture is not rapid enough *per se* to maintain the temperature above the ignition-point.

Since the chemical combination depends upon the collisions between molecules of methane and molecules of oxygen, it will be evident that, just as there is a lower limit of methane necessary for the propagation of flame, so there must be a lower limit of oxygen also. In mixture of air and methane the quantity of oxygen required for complete combustion is present in a mixture containing 9.6 per cent of methane—and this is about the most sensitive mixture with the lowest ignition point. A diminution either in the quantity of methane or in the quantity of oxygen raises the ignition-point. It would appear also that the lower-limit of methane is raised by a diminution of the oxygen content of the air; so that whereas 5.7 is the least percentage of methane in ordinary air that will explode, a sensible diminution of the oxygen in the air will raise the percentage of methane necessary to propagate a flame to over 6 per cent of the mixture. We have found that an atmosphere in which the oxygen is reduced from 20.9 to 13.5 per cent, will still propagate flame when mixed with pure methane and fired by a spark or a small detonation. Since the value of the lower-limit mixture of methane and air depends upon the rapidity of chemical action, and since this depends on the frequency of the more violent collisions between the molecules of methane and oxygen, it might be inferred that the higher the initial temperature the lower the lower-limit of methane would be. This inference has recently been confirmed experimentally in our laboratories. Mr. A. Parker has shown, in the case of a number of gases, that a mixture which will not propagate flame at 15 deg. Cent. will do so at 100 deg. Cent. under the same pressure: and Messrs. Ramsbottom and Hobson have shown that when mixtures of methane and air are heated up by adiabatic compression above their ignition-point, the whole of the methane is burnt although its percentage may be only one half that required to propagate a flame at ordinary temperature and pressure.

The presence of a chemically inert gas, such as nitro-

* Paper read before the Manchester Section of the Society of Chemical Industry, and published in its *Journal*.

gen, argon, or carbon dioxide, in a gas mixture retards the rapidity of combustion partly by its "diluting" effect, which prevents the collisions of chemically-active molecules, but mainly by its absorption of heat. The damping effect of an inert gas on the velocity of the "explosion-wave" can be calculated very nearly from its density and its specific heat. An incombustible dust particle might be inert in the same way, and damp down a flame by absorbing heat. On the other hand, it has been shown, as in Prof. Bone's well-known experiments, that the combustion of gases can be concentrated and "hurried up" by means of suitable heated surfaces.

If it be assumed that for the transmission of flame from layer to layer in a mixture of methane and air, there must be sufficient methane in each layer to give out enough heat in burning to raise an equal layer of the mixture to its ignition point, then it is clear from the known heat of burning of methane that a much less percentage of methane in air than 5.6 should be sufficient theoretically to propagate flame under normal conditions. Would it be possible for dust particles suspended in a gas mixture so to concentrate the combustion near their surfaces as to bring down the lower-limit of methane necessary to propagate flame from 5.6 to a point near this theoretical limit? Such is the question raised by Abel's interpretation of his experiment.

ABEL'S EXPERIMENTS.

The Seaham disaster in 1880, when it was not generally recognized that coal-dust played any important part in mine explosions, led to an investigation by Abel into the effect of suspending a cloud of coal or other dusts in a current of air containing small quantities of fire-damp. The experiments not only demonstrated that suspended coal-dust made such weak mixtures highly explosive, a fact already insisted on by Galloway, but led to the definite conclusion that a fine cloud of such incombustible dusts as calcined magnesia or kaolin would render explosive a 3 per cent mixture of fire-damp and air.

The apparatus employed in Abel's experiments was a rectangular gallery, 28 feet long and one square foot in section, provided with a steam-jet to produce a draught at one end, and with the other end open to the air. Near the open end was the gas inlet and a short distance "in-bye" was a drum-sieve to drop the dust into the current from above. Sixteen feet from the drum-sieve a lamp was placed opposite a window in the gallery. The fire-damp was a natural gas issuing as a blower from the Wigan 9-foot seam at the Garswood Hall Colliery.

Abel thus describes the observations made:

"A gas-mixture having 3 per cent of fire-damp was allowed to pass a lamp-flame, at a velocity of 600 feet per minute for some time; no result was produced, but on causing it to convey calcined magnesia in suspension, long flares of flame were produced within a few seconds of the mixture first passing the lamp, and the inflammation speedily spread throughout the gallery with feeble explosive effect. With only 2.75 per cent of gas, results quite similar were produced, the *general* ignition following, however, less rapidly after the first production of the flares in front of the lamp-flame. With another sample of calcined magnesia, which was not quite so light as the first one, a corresponding result was obtained with a mixture containing 3 per cent of fire-damp.

"These remarkable results led to the trial of a number of other non-combustible powders or dusts, which are not chemically affected by such heat as they would be exposed to in the flame of a lamp (such as kaolin, powdered flint and other forms of silica, pumice, slate dust, etc.) with results similar to those furnished by the magnesia-dust, but more or less affected by variations in the density, and other physical properties of the dusts."

Abel at first attributed the effect of the incombustible dust to "the localizing and intensifying" of the chemical action by the heated particles which he imagined might be carried in a state of intense incandescence into regions of unburnt gas—and so "carry the flame" along. But later on he considered the action was catalytic—similar to that of finely divided platinum on mixtures of hydrogen and oxygen.

In considering Abel's experiments it must be borne in mind that the dust-cloud not only rendered the gas mixture explosive after it had passed *beyond the lamp-flame*, but conferred on the current *before it reached the flame* the power of propagating flame backward.

In 1882 Mallard and Le Chatelier[1] published an experiment in which they showed that incombustible dust, such as magnesia, when suspended in a rising stream of gas and air, did not render it more inflammable; but when the dust was allowed to fall through a flame into the upward stream, the particles remained incandescent and were surrounded by a blue cap during their fall. This result was quoted by Abel as confirming his conclusions.

During the past year several sets of experiments have been made at Eskmeals in a gallery similar in dimensions to that used by Abel. The gas and air, however, were thoroughly mixed before entering the gallery by means of a powerful Sirocco fan which drove them forward past the lamp-flame placed at a window sixteen feet distant from the fan-drift. The magnesia was introduced in a stream into the gas and air mixture before it entered the fan. Experiments made with coal-gas and air, and with pentane gas and air, failed entirely to show any increased inflammability of the gas mixtures due to the suspended magnesia. Moreover, the "flares" observed in the gallery when the mixtures were brought above the lower-limit were not the halos or clouds described by Abel, nor did the inflammation, when it spread backward, through the gallery, do so "with feeble explosive effect." The "flares" roared, and rapidly charred wood, and on one occasion set fire to timber near the orifice of the gallery; and the "general inflammations" were very distinct explosions. Experiments made in a small wooden gallery 4 inches square gave precisely similar results; by making one side of the box of glass, the caps and flares and the general inflammation can be readily observed.

Meanwhile, experiments made at Eskmeals by the Home Office Committee and their chemists had shown that the flame traversed explosive mixtures of gas and air more rapidly when dust-free than when laden with magnesia dust, and the pressures attained were also less when incombustible dust was present. In our laboratories here we found that of a number of gaseous mixtures just below the lower-limit and therefore incapable of propagating flame when sparked, none of them could be made explosive by shaking up incombustible dust in them. On the contrary, it was found possible to start with a mixture which was just above the lower-limit, and make it non-explosive by stirring up dust in it. We then endeavored to test Abel's hypothesis in another way. Glass vessels were fitted with fine platinum coils which could be heated up electrically in contact with various mixtures of gases. If magnesia can render a non-explosive mixture of methane and air explosive by its catalytic action, *a fortiori* platinum might effect this result. We found, of course, that mixtures above the lower-limit could be exploded by heating the coils rapidly; but when the coils were heated slowly until chemical action began on the surface and the electric current was then switched off, the coils glowed for some time but no inflammation occurred. Under no conditions that we could produce was it possible to make a non-explosive mixture explosive by inducing combustion of a portion of the mixture.

On the other hand it is easy to illustrate the quenching effect of magnesia on an actual explosion by filling a long horizontal glass tube with an explosive mixture of gas and air, and placing a spoonful of magnesia in the tube. A fairly rapid flame on reaching the dust throws it up and is extinguished promptly.

When these, and other experiments, made it impossible to accept the catalytic hypothesis, we endeavored to produce more nearly Abel's experimental conditions. Dr. W. Kellner, Abel's assistant at the time, was fortunately able to tell us two important details which had not been published—viz., that the gas was admitted through a tube entering the bottom of the gallery, and that no special device was used for mixing the gas and air as they were drawn along the sixteen feet of gallery between the point of entry of the gas and the lamp-flame. On bringing in the gas-supply through the bottom of the gallery so as to mingle with the air current which had passed the fan, we found we could reproduce the appearances described by Abel. The "flares" were attenuated clouds of light—silent, and with hardly any charring effect. Occasionally they progressed along the gallery as detached filaments of flame, distinctly separated from one another. When the gas pipe projected a little into the gallery the stream of entering gas flowed upward through the air current, so as to fill the upper portion with a feebly explosive mixture while the lower portion was uninflammable. When the gallery was so filled a lamp-flame five inches from the floor showed only a small cap, but ignited the mixture above if the flame was raised a few inches. The flame then traveled back against the current with "feeble explosive effect." On pouring the magnesia through a drum-sieve into the gas and air current, just after the point of entry of the gas, the cloud of dust made the flares more luminous, and every now and again a particle of dust passing through the lamp-flame was whirled upward white-hot into the explosive mixture above and ignited it.

Exactly similar appearances are observed in the small wooden gallery when the gas is admitted from below and the gas and air streams are allowed to mingle as they flow along. This method of mixing seems to result in long "threads" of gas being borne along which break into detached filaments. These threads or filaments may be ignited and the resulting thin detached flames may be carried some distance, although the gas if thoroughly mixed with the air could not be ignited. A sample drawn from the gallery during the "run" would not reveal the heterogeneity of the atmosphere, but would give the average contents of that portion of the gallery. This fact may account for Abel's statement that mixtures of methane and air containing between 3½ and 4½ per cent of methane, when drawn over a lamp flame, without any dust present, gave lambent flames that increased in size and after some seconds caused a general ignition.

The pretty experiment of Mallard and Le Chatelier may be easily adjusted to show the inertness of magnesia (or other incombustible dusts) when it is carried upward by the ascending current of gas and air into the Bunsen flame above, and the effect such incombustible particles have when they are dropped through the Bunsen flame and fall red-hot through the rising current. A glass tube 5 feet long and 3 inches in diameter is fed from below with a mixture of gas and air through a Mecker burner and an adjustable orifice. A Bunsen flame burns horizontally across the upper open end. When the gas and air mixture is weaker than the lower-limit the hot particles carry down a small cap with them; but when the mixture is above the lower-limit and would propagate a flame if it were not moving upward faster than the flame can travel downward, then a heated dust particle carries a real flame in its wake as it falls, and the flame spreads outward in an inverted cone.

When the mixture is just strong enough to propagate a flame downward, the heterogeneity of the mixture is one over another—giving an appearance which has suggested a swarm of luminous jelly-fish.

The Le Chatelier experiment in no way confirms Abel's hypothesis, but on the contrary it adds strength to the contention that incombustible dusts have a cooling and therefore a quenching effect on flame. Their presence in a mine cannot add to the danger of fire-damp explosions.

[1] *Annales des Mines*, 1882.

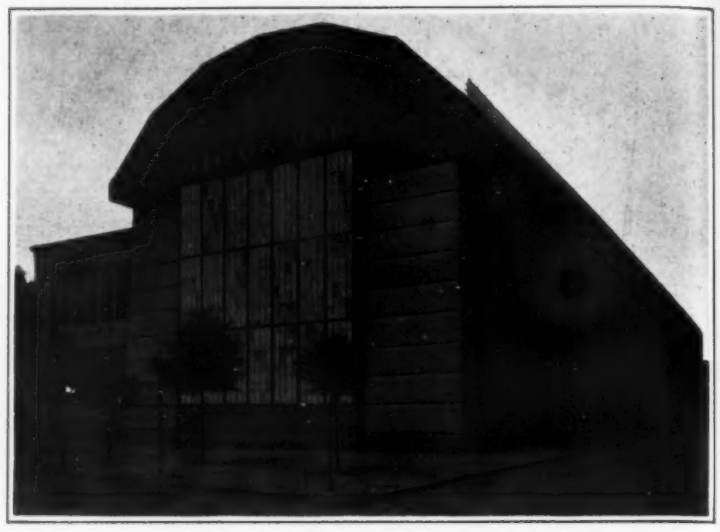
Imports of Olive Oil Not Adulterated

FOLLOWING the receipt of several inquiries as to whether a large part of the olive oil imported into the United States is adulterated with cotton-seed oil, the Department of Agriculture has made a special investigation into the state of the olive oil admitted. The Government's interest in the matter is two-fold: first, to protect the people from getting adulterated olive oil; second, to protect the reputation of olive oil in the interest of olive oil producers in California, Arizona, and other olive-growing sections. Since 1900, the Department, through its various port laboratories, has examined samples from 2,149 importations of olive oil. Of these, only ten were refused entry, and only three of these were refused entry for containing cotton-seed oil. These cotton-seed oil adulterations date back to 1908, when two shipments were found to be adulterated, and 1909, when one shipment was found to be adulterated. Since that time, there has been no shipment which has given evidence of cotton-seed oil adulteration. In 1910, seven shipments of olive oil were refused admission because adulterated with peanut oil, and since that time there have been no cases discovered of either cotton-seed oil or peanut-oil adulteration. The addition of cotton-seed oil to olive oil, the Government specialists report, is very easily detected. Indications therefore are that all olive oil admitted to the country and branded as olive oil has been pure olive oil, and has contained no cotton-seed or peanut oil. Occasionally the Government discovers shipments of sardines in which the olive oil contains some cotton-seed oil. The experts point out that it would be illogical for the importer to bring into this country olive oil adulterated with cotton-seed oil, and pay a duty of 50 cents a gallon on the cotton-seed oil that is contained in the mixture. Similarly, nut oils are admitted under the tariff act, and the specialists say that it would be absurd for an importer to bring from Holland olive oil adulterated with peanut oil, and pay a duty of 50 cents a gallon on the mixture, when he could bring them over separately and avoid paying any duty on the nut oil.—*Journal of Industrial and Engineering Chemistry.*

Demand for Radium

GERMANY is stated to have purchased for hospitals and medical institutions every available milligramme of British-made radium. In an interview with the British Radium Corporation it was admitted, says the *Standard*, that an extraordinary demand had developed recently for British radium. The price of radium today is £16,000 per gramme.—*The Engineer.*

Large-unit machine works of the A. E. G. in Berlin.



Turbine factory of the A. E. G. in Berlin.

The Aesthetics of Industrial Buildings

Beauty in Perfect Adaptation to Useful Ends

By Prof. Peter Behrens

A DISCUSSION on "Aesthetics and Industrial Buildings." on account of its close connection with the problem of modern civilization, is one of the most important of present-day unities. While our age is in its achievements inferior to no other age, its characteristics are of a different kind. The most imposing manifestations of our capacities are, in fact, the results of modern engineering. Our advances have created an astoundingly high standard of material life, such as had never been reached before in history.

While life without the material benefits of modern engineering and its unceasing progress would be now unthinkable, modern life exhibits a pronounced craving for culture and a keen longing after civilization in all fields of art. Still, modern life fails to show the characteristics of a mature civilization, there being no contact between the realms of art and engineering. While architects frequently are still intent on deriving their æsthetical values from the forms of past centuries, engineers in their constructions are only interested in construction itself, and are content with this result obtained by mere calculation. The two important fields of human activity, art and engineering, are thus unfortunately left side by side without any mutual influence, and this dualism of our age prevents the unity in form which is the condition and at the same time the proof of existence of a style, from coming into being.

The last fifty years have placed before the engineer tasks so difficult that his ingenuity was alone at work, leaving him no thought for æsthetic creation. Still, his productions often are not lacking in a certain beauty, e. g., in large iron halls with their lofty roofs, which give an impression of grandeur. To these may be associated extensive factors and other buildings, that are closely connected with industry or traffic.

In connection with the high-tension works of the Allgemeinen Elektrizitats Gesellschaft, near the Humbolthain, built by myself in 1909, I endeavored so to arrange the various parts of the building in the ground-plan that they might form with the existing structure compact courtyards as large as possible, which would be of importance not only from an æsthetic point of view but at the same time for the operation of the works. Moreover, the forms of the façade had only to be adapted to the laws of proportion without using any ornamental decoration, so as best to become an exterior expression of the interior. The working out of the designs for the turbine-hall of the Allgemeinen Elektrizitats Gesellschaft, in Huttenstrasse, offered special interest from the combined use of the two materials, iron and glass. Iron has facilitated the present success of statics in allowing the minimum of material to be ascertained for each given construction. It exerts, as it were, a dematerializing influence. Architecture is formation in space. In order to insure space effects as complete as possible with iron and glass as building materials, the hall was constructed of three-joint arches, warranting the greatest obtainable clearness of space. In order to insure the desirable compactness of form in external appearance, an impression of plane walls limiting the structure had to be obtained. This seemed to be best realized by combining the iron and glass mainly in one plane. The compact surfaces thus obtained will more largely give the impression of true surfaces, as the elements of some structural importance produce stronger shadow effects. These binders, visible at the outside, are not made up of a framework, but in order to produce a compact impression, comprise continuous walls.

A compact surface was also produced in connection with the huge front window, which seemed the more imperative as the window of the façade is the carrying part that the heptagonal gable is allowed to rest on. The two corner pillars, being only intended to connect and to close, are made of a different material, concrete, its horizontally arranged structure forming an intentional contrast with the verticality of the construction.

These and similar principles alone will allow compactness and a feeling of æsthetical stability to be produced by means of an iron-glass structure. Without such means this stability, which is distinct from that of the constructive, would be hidden from the eye used to sensuous impressions. Engineering structures are the results of a mathematical mind. Nobody doubts their stability based on calculation, but it is another question whether our eye perceives a dynamical impression of stability, which is an æsthetical condition perfectly complied with, for instance, in the Doric temple.

Architecture always has a tendency to uniformity and compactness. This, instead of by surfaces, can be complied with by a uniform sequence of structural elements. An instance of this is the administration building of the Mannesmann Tube Works at Dusseldorf built by myself, the architecture of which comprises a continuous sequence of pillars. However, this æsthetical intention was at the same time bound to benefit the practical requirements of the building, the arrangement of the ground-plan being based on the idea that instead of delimiting rooms of a given size, by means of masonry walls, each story was to be considered as a free area to be subdivided at will. The powers of organization and the personal liberty of the director of a large industrial works were in fact to be hampered by no pre-established boundaries. The various stories had to be adapted for subdivision into rooms of any dimensions in accordance with actual requirements, producing either a number of small offices or a few straightforward large halls. In the place of outside walls into which the windows are cut, an open system of pillars determining the terminal points of a standard room is therefore arranged, and these standard rooms are separated from one another by removable sound-proof double walls, the space left between the pillars on the window side being used for the installation of shelves for the files. As the corridors are kept clear by the open row of pillars and as they lead in gallery fashion round the courtyard, they can be of a comparatively small width.

It is now interesting to decide who is to design an industrial building. All buildings of previous epochs came from one hand, the architect designing and carrying out simultaneously the expression of beauty and the grandiose constructive idea. This

High tension factory of the A. E. G. in Berlin.

Office building of the Mannesmann Tube Works at Düsseldorf.

is how Signardo the artist used to build fortresses and military machines. Neither the artist nor the engineer can at present combine several special professions. Engineering is a difficult scientific profession which, in view of present-day requirements, demands an absolute devotion. But artistic creation is likewise a profession in itself which fills the thinking and feeling capacities of a man and which like any other profession requires protracted study. However, an adequate appreciation of new creative ideas and higher aims is first of all to be expected from the engineer. I think that the engineering buildings of the future as well as the products of industry will have to be developed to perfection of form. We all feel the incongruity of an industrial building suddenly arising in beautiful scenery, a structure of a style which even in a suburb or industrial town would hurt our feelings, and we therefore think that artistic care should be bestowed on such buildings, to insure a simple style subject to artistic laws. The question, however, is: Who will have to design such buildings? It is not likely that before a generally recognized artistic tradition has been restored, a special profession, that of the "architect-engineer" should be developed; the nearest future will rather witness a close cooperation of artists and engineers. If our feelings are now hurt by a power-house interrupting the rhythm of lines and materials in an architecturally well arranged street, it is likewise a mistake for the architect designing an industrial building, to cover by his materials all cleverly-calculated constructions, thus adding something quite strange to the purpose and to the internal organism of the building. In fact, the internal organism of a building set apart for industrial use, should be kept especially straightforward, and this organism should give rise to a new beauty, characteristic of the spirit of the times. All great things that have been produced in the world have been the results not of conscientious professional work, but the outcome of the energy of great and strong personalities. In my opinion it is indifferent whether the conception of important modern works is due to the initiative of a broad-minded technically-skilled architect or of a rhythmically feeling artistically-skilled engineer, or whether a third one as a broad-minded organizer supplies the fundamental idea, associating the architect and the constructor with himself and his work. The main thing is that the character of modern style should be realized and carried out and that such architects and engineers as possess the required creative power and sure stylistic feeling, should get recognition. Industry is in a position to create great values of national and economical importance, the general rise of taste being after all an economic problem. This entails a conversion of intellectual work into material factors. The culture of taste pervading a whole nation is after all a testimonial of the capacities of the nation.

Gustave Eiffel

Builder of the World's Highest Structure and One of the Foremost Authorities on Aerodynamics

ALEXANDRE GUSTAVE EIFFEL was born at Dijon, December 15th, 1832. Immediately after graduating from the Ecole Centrale des Arts et Manufactures, in 1855, he devoted himself to the study of construction in steel, which was destined to form his life work.

In 1858 he was intrusted with the construction of a steel bridge at Bordeaux. In the foundation of this bridge Eiffel was one of the first to make use of compressed air. He afterward built the bridges at Bayonne and those of the main line of the Orleans Railway at Floirac and Capdenac, where he applied an improved system of sinking hollow piles with compressed air and the aid of a hydraulic press.

In collaboration with M. Krantz, the Director of the Paris Exposition of 1867, Eiffel made the calculations for the arches of the machinery building, verified, by experiment, the results of his theoretical studies and determined practically the coefficient of elasticity for large iron constructions which is now generally used.

In 1867 Eiffel founded at Levallois-Perret an establishment for iron and steel construction which was operated under his direction until 1890, when it was transferred to a stock company. This company is still engaged in executing very noteworthy constructions in steel and great contracts in general under the direction of Eiffel's former engineers. M. Clery, whose sketch of M. Eiffel is here quoted from a recent issue of *L'Aerophile*, regards the improvements which Eiffel introduced in assembling his structures as the most remarkable part of his work. By these improved methods Eiffel succeeded in placing with boldness and precision trusses and bridges of lengths which were then quite exceptional. In particular, he improved the placing of straight bridges by devising a tipping frame and applying it to spans for which this method was considered impracticable, notably in the case of the Tarde viaduct, which included a span of 330 feet. Eiffel subsequently introduced and made common in mountainous regions the employment of the method of indirect bearing for long straight bridges, like the bridge at Cubzac, and for great steel arches, like those of the bridges at Porto and Garabit. Finally, Eiffel invented and made popular demountable and portable bridges for military and colonial use. He constructed bridges of this type to a total length of many thousands of yards, for which he received a number of prizes.

It is proper to observe that most of Eiffel's commissions were granted as a result of international competitions in which the most important European constructors took part.

In the construction of the first viaducts supported by steel piles at Neuvial and the Sioule River on the railway line connecting Commentry and Gammat, Eiffel perfected this type of construction, which he afterward applied to the viaducts of the Beira Alta and the Douro railways, in Portugal, and to the lateral viaducts at Porto and Garabit, where the highest pile reached the then unknown height of 200 feet.

Among Eiffel's great works may be mentioned the viaduct of the Oise, the railway bridge over the Tarde, the railway and carriage bridges over the Tagus and at Vianna in Portugal, the Cubzac bridge over the Dordogne, a number of bridges in Cochin-China, the great arched bridge at Szegedin in Hungary, the bridge at Porto over the Douro, in Portugal, and the bridge of Garabit on the railway line between Marvejols and Saint-Flour, one of the most important and remarkable works of the kind in France.

Among other constructions of Eiffel may be mentioned numerous steel frame churches, markets, gas works and railway stations in France and abroad, the Ecole Monge, the Hotel du Credit Lyonnais,

Mr. Gustave Eiffel standing in the experimental chamber of his new laboratory.

the Musée Galliera, part of the Bon Marché shops in Paris, the Custom House buildings at Arica, Peru, the monumental railway station at Budapest, the monumental gallery forming the principal façade of the main building of the Paris Exposition of 1878, the wharves of the Paris Gas Company at Clichy, the Port-Mort and Port-Villez dams on the Seine, and the dome of the great equatorial telescope of the observatory at Nice. For this last-mentioned work the Academie des Sciences awarded to M. Eiffel the Monthyon prize in mechanics, in 1889.

In 1887 the Panama Canal Company, having decided to abandon the construction of a tide-water canal, intrusted to Eiffel the general plan for a system of locks. Eiffel performed the necessary work with an energy which was universally recognized and which should have assured the accomplishment of the great enterprise, but the work was unfortunately arrested in 1889 by lack of funds and the bankruptcy of the company. In the course of the judicial investigation which followed M. Eiffel was fully exonerated and the injustice of the attacks made upon him was demonstrated by the Court de Cassation from the judicial point of view and by the Council of the Legion of Honor from the moral point of view.

With the exception of the Garabit viaduct, the most important work of M. Eiffel is the tower, one thousand feet high, which bears his name and stands on the Champ de Mars in Paris. Constructed in connection with the Universal Exposition of 1889, this colossal tower which M. Alphand, at the time of its erection, called the masterpiece of iron construction, has furnished to science a valuable observatory where numerous meteorological and physical researches are continually carried on, and it also affords to the public the most interesting of panoramas. The Eiffel tower, furthermore, is destined to play an important part in wireless telegraphy because of the exceptional height to which the antenna can be carried. The new equipment which is now being installed in the tower by the War Ministry will make this the most powerful station in the world.

Eiffel has acted as president of the Society of Civil Engineers and of the Association of Graduates of the Ecole Centrale. He is an honorary member of most of the great scientific societies of Europe and America, a laureate of the French Institute, an officer of the Legion of Honor, an officer of Public Instruction, a Chevalier of the Austrian Order of the Iron Crown, a Commander of the Orders of Concepcion (Portugal), of Isabella the Catholic (Spain), of the Crown (Italy), of the Holy Saviour (Greece), of Saint Anne (Russia), Saint Sava (Servia), etc.

Since 1890, after the completion of his career as engineer and constructor, during which he had executed contracts of a total value of $28,000,000 and had used more than 100,000 tons of iron and steel, Eiffel has devoted himself entirely to scientific research. He has published many scientific works, including an exhaustive monograph on the Eiffel Tower, Practical Studies in Meteorology, a Meteorological Atlas of France, Experimental Researches on the Resistance of the Air, and a great number of articles on meteorology.

Eiffel has undertaken the elucidation by rational and methodical experiments of the aerodynamical problems which the progress of aviation is constantly making more urgent. His studies, which began in 1903, and are still in progress, have already yielded results of the very greatest interest by reason of the errors which they have corrected, the new and unsuspected facts which they have revealed, and their immediate applicability to the practice of aviation. Thus, after so industrious and successful a career, the illustrious engineer will enjoy the additional glory of figuring among the founders of experimental aero-dynamics, and of contributing in large measure to the improvement of purely mechanical aerial locomotion.

Volume of Water Upon the Earth

IT is calculated by Halbfass that the total volume of water upon the earth's surface amounts to about 313 million cubic miles, which are distributed as follows:

Ocean	312,000,000 cubic miles
Polar ice masses	840,000 cubic miles
Lakes and ponds	60,000 cubic miles
Rivers	12,500 cubic miles
Atmospheric moisture	2,952 cubic miles
Marshes	1,440 cubic miles
Snow	67 cubic miles

Since the total volume of the earth is 259,000 million cubic miles, it follows that the water constitutes about 1/830th of the earth's total capacity.—*Cosmos.*

Curiosities of Binocular Vision

Stereoscopic and Other Effects

By Frederic Campbell, Sc.D., Department of Astronomy, Brooklyn Institute

THE monocle might have been the usual optical aid instead of spectacles. For monocular vision might have been the rule instead of binocular—sight with one eye instead of two. It is a remarkable biological fact that

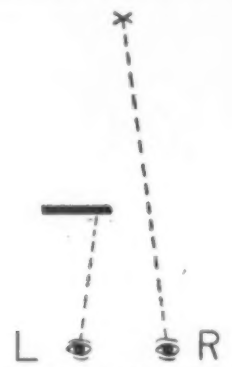


Fig. 1.—Showing how the right eye may continue to see an object, the observer being unconscious that left eye's vision is obstructed by intervening object.

all creatures, not endowed with a multiplicity of eyes, possess two-eyed vision.

In the case of man, it is to-day, as it always has been, a mystery that the two images obtained by the two eyes, in spite of not being perfectly identical, blend into one. Disturb one eye with the finger, and the two images become apparent. A person, one of whose eyes turns out, must always have two distinct images; but he trains himself to ignore one of the two, either by alternation, or by discarding the services of one eye altogether. In the latter case atrophy sets in and the eye degenerates to practical uselessness. That we can see with one eye, to the exclusion of the other, is apparent from the fact that the approved way of using the microscope or telescope is to keep both eyes open, but to ignore what is seen by the eye not at the glass. Practice makes perfect in this as in all things else.

Animals having their eyes located on the sides of their cannot direct both eyes to the same object, and hence must see two quite distinct images. Man's two eyes being in front, he is favored in being able to look directly forward to a single object. But many lower animals have a wider sweep of vision on both sides and even behind.

Man sees with both eyes nearly all the time. One eye helps the other, the two producing a unison effect. If a man lose an eye, however, he is little disabled, and can get on very well, daily demonstrating the wisdom of duplicating so important and well nigh essential an organ, thereby saving many from blindness. We often see with a single eye when we are not aware of it, both eyes being open and supposedly doing the seeing. For example, let one be at a public gathering. Some one so sits in front

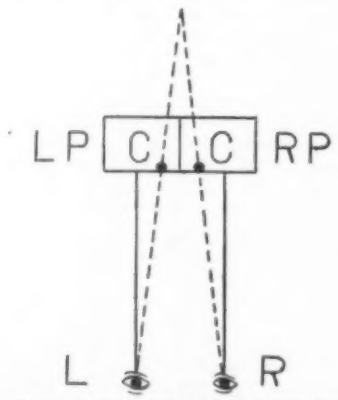


Fig. 4.—Straight stereoscopic vision, showing how each eye looks at its own half of picture, the two halves blending into one in the mind, with sense of distance because of straightness of vision; while objects placed nearer each other cause convergence of the eyes, and consequent sense of proximity.

of him as to interfere with the left eye seeing the speaker. The right eye, however, has an unobstructed view, and he does not realize at all that the left eye is out of commission. But let him close the right eye, and he will see that the speaker is gone from view. Now let him open it again and, instead of so closely observing the speaker let him observe what his eyes are doing. He will find, himself able to divide his attention between the two eyes. He will notice that the right eye sees the speaker plainly; and then, right over the speaker's entire form, he will notice that the left eye has cast the outline of the person who sits in front of him; so that, without closing the right eye at all, he can see just how far the person before him covers the view of the speaker and his surroundings. Then, by closing the right eye, he can confirm this discovery. We are often placed in closely crowded conditions, where one eye is doing all the seeing, because the view of the other eye is obstructed. We seem to see just as well that way for the time; for two eyes certainly do not double either the brilliancy or the clearness of our view. But, when attention is called to the fact that one eye alone is looking, a sense of discomfort arises, making the situation quite intolerable if continued for any length of time.

Within certain rather close limits, binocular vision is of great service in enabling us to judge of distance. There is a certain "parallax" obtained between the two eyes, though they are separated at their centers by only about 2½ inches. One may demonstrate this to his own satisfaction by standing in a furnished room of not more than 15 or 20 feet length, and looking first with one eye and then with the other. He will immediately discover that, by that operation, he is causing objects before him to shift from right to left, and from left to right. Let us suppose, for instance, that a lamp stands upon a center table. Closing the left eye and looking at the farther wall throws the lamp to the left; closing the right eye throws it to the right. And the nearer the object is the more it will be thus displaced in a fixed mathematical

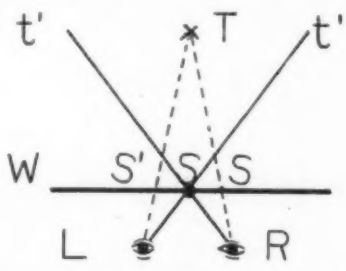


Fig. 3.—In looking through window-pane *W* at tree *T* a spot on the glass *S* is seen as two spots at points where the two lines of vision pass through the glass. But in looking directly at the spot, two trees appear where the lines of vision terminate.

ratio. This is what is called "parallax" in astronomy, the apparent moving of an object, due to the actual moving of the observer. In looking first with one eye and then with the other, the observer is changing position by about 2½ inches.

The principle involved in this is ever operative. With both eyes open, and the attention fixed on the farther wall, the right eye sees farther around the right side of the lamp, and the left farther around the left side of the lamp; and the mind becomes dimly conscious of the solidity of the lamp, the sight feeling its shape as the hand might do. The mind moreover dimly appreciates a duplicity of images of the lamp, and reaches conclusions as to its distance, based on the distance of these two images from each other. Let one hold up his finger, and then look at the wall behind the finger; he will be conscious of seeing two fingers, and he will judge of the distance of the actual finger by the distance apart of the two apparent fingers. A spot on the window pane, doubled as one looks through it across the street, illustrates the same principle. It is clearly in part by this method that we arrive at ideas of space and distance.

Beyond certain limits, however, the parallax between the two eyes amounts to little, as in viewing a distant landscape. Alternation between the eyes will show that distant objects cannot be made to shift their position on the general background. Their distance must be gathered from other considerations. Were our eyes farther separated, greater parallaxes would be possible, and a clearer discovery of the space relationships of distant objects. This is secured by Zeiss, the well-known German inventor and maker of telescopes, when he spreads his object glasses several feet apart, and brings the light rays to the two eye pieces by means of refracting prisms. He thus enables one to see not merely the woods, but into the woods, not merely the crowd, but among the crowd. This enables one to judge of the relative distances of faraway objects, as he could not when using the same power in ordinary straight binocular glasses.

It is this principle which raises astronomers to the dignity of high achievement when it enables them to ascertain the distance of many of the nearer stars—some 300 of them having been thus measured. So far is the near-

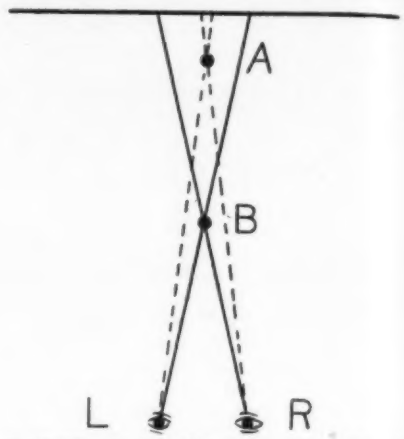


Fig. 2.—Parallax in binocular vision. The nearer object necessitates greater convergence of lines of vision, and these meet the distant wall farther separated for near than for far objects.

est star that no glass could be constructed giving sufficient parallax. But by reason of its distance of 93,000,000 miles from the sun the earth itself provides a parallax if observations of a star be taken six months apart; for then the observing points are 186,000,000 miles apart, and the shift of the star, if any be discovered, reveals mathematically what is its distance. Stellar distances are thus measured from 4 1/3 light-years up to 200 light-years—a light-year meaning the distance that a star's light travels in a year. Alpha Centauri, for instance, nearest star of all the heavenly host, sends its light to us in 4 1/3 years; Antares in 200 years. But the great mass of the stars are too distant to be at all affected by the enormous swing of the earth from one side to the other of its orbit.

A very simple but effective device was long ago invented to enable one to secure in pictures the same space effect that he obtains in looking at actual scenery. This is called the stereoscope. Once it was popular enough to be found in almost every home. Of late years it has been unfortunately neglected. But now there is a decided revival of interest in stereoscopy, and justly so. The trouble with the ordinary picture is that it is printed flat. It has in reality no depth whatever, and obtains "perspective" only by certain devices of the artist and certain inferences of the mind of the observer. The way nature gives us sense of perspective most satisfactorily is by binocular vision, wherein she gives a slightly different picture to the right eye from that presented to the left. Different though they be, these two blend into one, but in such a way that we perceive the space relationships of the objects seen, almost as if we felt them with the hand; and this is exceedingly satisfactory.

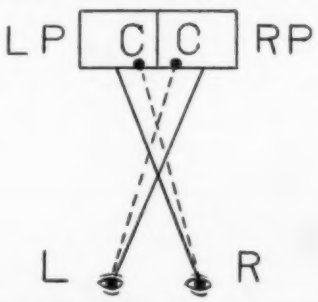
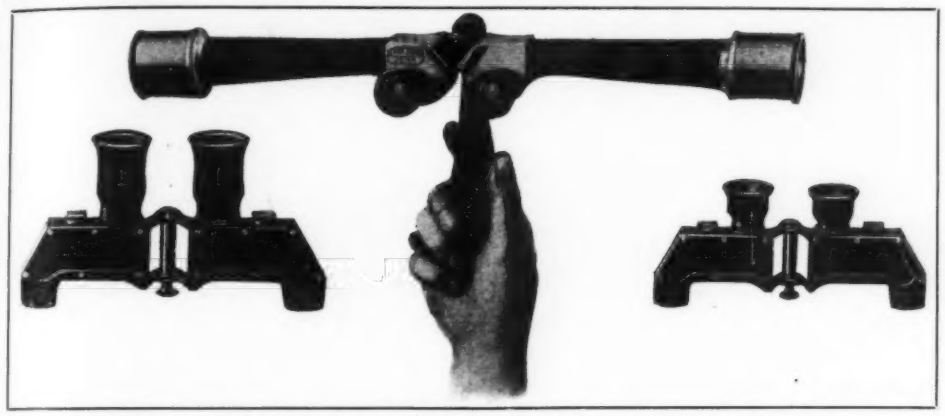


Fig. 5.—Illustrating crossed vision. The right eye looks at the left picture, and the left eye at the right, the two blending into one in the mind, at point where lines of vision cross. Bringing objects nearer each other in the two halves, causes lines of vision to converge less and straighten toward parallels, thus pushing back the point of intersection and giving sense of greater distance.

Now the stereoscope succeeds in giving the same impression, by placing in the little instrument a double picture, one side of which is different from the other in such a way that the blending of the two images into one gives the same sense of perspective that one often obtains with the unaided eyes. As one looks through the stereoscope, if he will alternate between one eye and the other, he will see how the scene shifts, the nearest objects shifting

most, just as in the room; and, therefore, the instant that he looks at a true stereoscopic picture with the stereoscope, he gets the impression of the naturalness of the view, the perspective, the space relationship of things; it is almost as if, instead of looking at a flat picture on paper or on the wall, he had stepped to the window and were looking out on the actual landscape.

Delightful as are the results of stereoscopy, it is most unfortunate that only one can look at a time, and that, for most people, it requires the instrument. It is possible, however, to secure the stereoscopic view of a stereoscopic picture without any instrument at all. This the writer has demonstrated again and again. Unless the two halves of the picture be too widely spaced, let one



Zeiss teleplasts, showing wide spread of object glasses, and consequent parallactic power.

choose a point midway between them, and then, by strong effort of will, imagine that to be an opening, through which he is endeavoring to see a very distant scene; in doing this, let him for the moment disregard the pictures altogether. The effort to look at something distant will straighten the two lines of vision, so that there will come an instant when they will run straight through the two halves of the stereoscopic picture; then the right eye will suddenly pick up the right picture, and the left the left, and the blended picture will at once stand out, in all its space relationship, so beautiful that one will often exclaim with joy. While for most people this is hard at first, it can be made easy by practice; and it ought to produce no strain on the eyes, for it is nothing whatever but the straight distant vision to which all are accustomed. Only, to use the distant vision on a near object is the problem. In this way the writer has seen a picture of a comet stand out millions of miles this side of the background of stars.

Indeed, one can readily make a stereoscopic picture for experiment. Let him take two identical portraits, not too large, and space their centers not more than 2½ inches, perhaps a little less. Then, with an inked pen, let him carefully draw say an oblique line across the right one; and let him duplicate this on the left, only placing it a trifle farther to the right. Now let him view these stereoscopically, and he will find that these two lines have blended into one in such a way that there seems to be a wire hanging out in front of the face of the portrait and not resting upon it. Now reverse these; make the right picture left, and the left right. The two oblique lines are now farther separated than the rest of the picture, hence the wire will now appear behind the picture rather than before it; for the eyes must turn a little more toward each other to see the picture than to see the line; and it is the turning toward each other which means nearness, and the parallel vision that means distance.

Here is a splendid field for inventive genius, in applying the stereoscopic idea, or some other idea, to moving pictures. They are all flat. They do not supply the space relationships needed. No stereoscope would apply to double pictures at the distance of the stage; besides which it would be expense and annoyance to supply all spectators with special instruments. Some one must ascertain how to blend pictures on the screen in such a way that, while sitting in the audience, one may see all the relations of space and perspective, as if viewed in a small stereoscope or in nature itself. This has been attempted, but we judge not so far successfully, as otherwise the device would be in universal use.

It is impossible to turn our eyes outward; but we are every day and almost every minute turning them inward. In ordinary vision both eyes always look at the same object. When you look your friend "in the eye," you do it literally; both of your eyes look at one of his, and not at both of them at the same instant; your two eyes center on his one. But, just as there is the possibility of putting the stereoscopic vision on two distinct but similar objects without the use of an instrument, so you may look at a man's two eyes stereoscopically, and reduce him to a one-eyed monster, or rather, a three-eyed creature, for it may be regarded as one of the drawbacks of stereoscopy that a right and left "ghost" are always to be detected flanking the blended picture on which the vision is centered; but these are easily ignored and forgotten. To look at a man's eyes stereoscopically, one proceeds just as with a stereoscopic picture, selecting a midway point on the bridge of the nose, and right through that and through his head looking in imagination at some very distant object. The two eyes can then be seen blended into one, producing, as might be expected, an altogether unique effect. A certain physician, who devotes much attention to psychology, asserts that this is a powerful method whereby to persuade a man to take a certain course which you desire him to follow; that when he perceives himself searched by the deep penetrating stereoscopic vision, he will commonly cease resistance and yield to your argument. The writer is not prepared to vouch for this. It is apparent, however, that one cannot thus look into his neighbor's eyes without coming near him, and perhaps propinquity has as much to do with persuasiveness as stereoscopy.

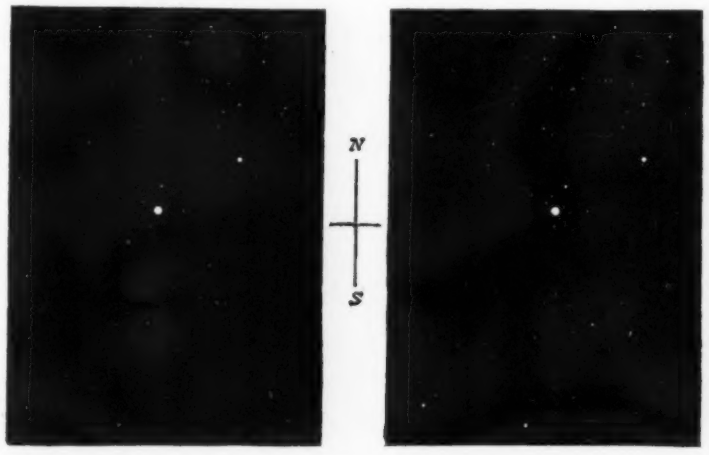
The fact that we can cross our eyes at will makes possible certain binocular experiments that are the reverse of stereoscopy and in some ways more interesting, even if not so useful. With stereoscopy the pictures must always be about 2½ inches apart and about 14 inches, more or less, distant. But in the crossed vision they may be any distance apart and any distance from the eyes. Moreover, in stereoscopy the ordinary person depends on an instrument. In the crossed vision no instrument is available, and the seeing must be done, if at all, with the naked eye.

Take the ordinary stereoscopic picture. Instead of viewing it with the straight stereoscopic vision one may cross his eyes and look at the left with the right eye and at the right with the left eye. Nor let any one fear injury from this process, unless the pictures be held too near; for it is the method of nature, in looking at near objects, always to cross the eyes; in reading, for example, the page is held so near that every man crosses his eyes in order to look at the same letters with both eyes at once. To cross the eyes on a double picture is not, however, a simple thing without instruction. And here is the instruction: Let the double picture be held a little farther than usual; let the head be held perfectly parallel to it, so that the line joining the two eyes will be parallel to the line joining the centers of the pictures. Then let the experimenter hold up a pencil or his finger between himself and the pictures in such a way, as determined by alternating the eyes, that the right eye will see the pencil or finger resting on the middle of the left picture, and the left eye will see the same on the middle of the right picture. Yet more helpful it may be to use a card containing a circular opening the size of half a dollar; through this the right eye must see the left picture, the left eye the right picture. Now look at the pencil or finger, or at the card if that be used. Immediately the two pictures will blend into one, right behind pencil or finger or opening in card. The vision may then be allowed to slip to this blended picture. Pencil, finger or card may then be removed, and the blended picture contemplated at leisure. The blend will seem to have come forward to the point of intersection of the two lines of vision, and to look smaller than it ought, for when seen so near, we should expect it to look larger.

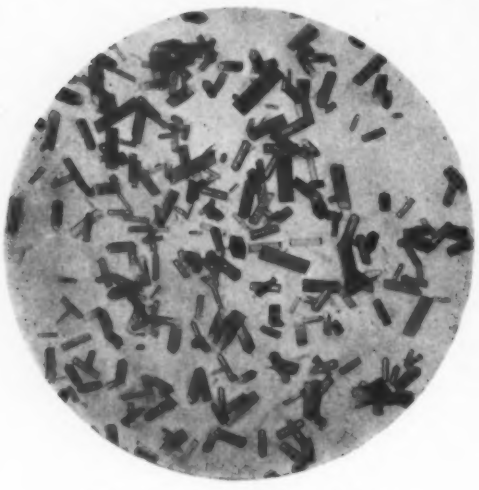
As already said, this same method may be followed with any two objects that are practically alike, even with similar buildings, church spires, mountains. In his own experiments with crossed vision, the writer has brought things together into one blended image as follows: (1) At a distance of 40 feet, two large blackboards, their centers 6 feet apart, so that identical reading on the two was distinct. (2) Two large blackboards, 18 feet apart, at a distance of 90 feet. (3) Two pairs of Indian clubs at a distance of 33 feet, the clubs being spaced 10 feet. (4) Two pairs of clubs, 4 feet apart, at distance of 35 feet, the blend preserved while approaching to within 7 feet. (5) Two pairs of large blackboards, spaced 10 feet between pairs, each pair with a small framed picture between, at a distance of 85 feet, all perfectly blended.

Most interesting is the blending of unlike objects and the making of "composite pictures." Whatever they are, one may be overlaid upon the other. Thus, pictures of an astronomer and of the moon have made possible a composite picture of "the man in the moon," and the right man, too, being an astronomer. A little image of a chicken has been placed in a glass of water, where it seemed unruffled, and from which it emerged as dry as a duck's back. But the blending of human faces is most interesting of all, a man's and a woman's, or two men or two women of very unlike appearance, contrasting colors of hair, etc. In this one will have to contend with the tendency of one eye or the other to shirk work. Though both eyes are open and their vision successfully crossed on the two faces, one will at certain moments see only the one face, and at others the other, as in the orchestra we observe only certain instruments; so that, by mental effort, we will have to prod up the lazy eye and require it to do its part of the seeing, that the two images may be mingled in the composite picture. I never discovered the likeness of a daughter's face to that of her father till I secured this kind of a composite; and then it was perfectly apparent; for naturally faces that are like will blend more perfectly than such as are unlike.

The method of crossed vision is spoken of above as being the opposite of the straight stereoscopic vision. It certainly is the opposite in that the eyes are crossed rather than straight; but it is also opposite, in that it reverses the perspective of the stereoscopic picture. Transpose the two halves of a stereoscopic picture, and then look through your instrument, and all is reversed; what was near is now far, what was far is now near. This is more readily perceived with pictures of figures, blocks, etc., than those of landscapes, where other elements than that of parallax enter into the sense of distance. Now when we cross eyes, we are doing the same thing as when we transpose the pictures; we put the near far and the far near. A comet, for instance, which, with stereoscopy, hangs charmingly in space this side of the background of stars, viewed with crossed eyes retires into a still more remote background, shielding itself with a screen of heavenly orbs.



Stereoscopic picture of Saturn. Viewed stereoscopically, the planet will be seen hanging in space, far this side of the stars.



Blood crystals of the Bengal tiger.

Blood crystals of the cat.

Blood crystals of the lion.

Our Life Blood

Family Likeness in Biological Species Laid Bare by Blood Tests

Among the tissues of the body the blood occupies a peculiar, though not quite unique position, through the fact that it is liquid. To be more exact, it consists of a liquid (about 52 per cent in man) containing various other constituents in suspension.

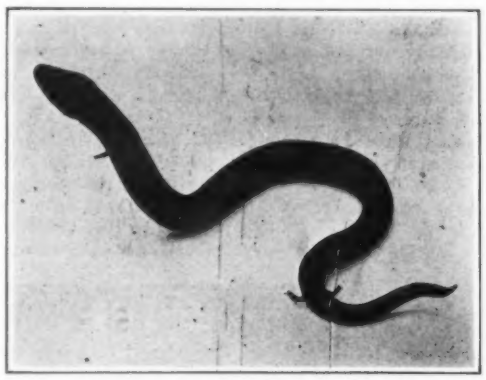
The liquid portion of the blood, the *plasma*, consists of about 90 per cent of water containing calcium salts, the chloride of sodium and potassium, phosphates, albumen and other proteids, as well as certain fatty constituents.

Floating in this liquid medium are several semi-solid constituents, which present features of special interest. Thus the white blood corpuscles behave very much like independent living organisms, having a motion similar to that displayed by the low animal organism known as the amoeba. They have also the power of "eating up" various undesirable intruders, such as disease germs, much as the amoeba takes in its food by the very primitive method of simply flowing around it and thus engulfing it. Then there are the white blood platelets, whose function is not well known. They are found in abundance in mammalian blood (200,000 to 600,000 per cubic millimeter, of which 16,386 make one cubic inch) but are absent in the blood of birds, amphibians and fish.

But, to the lay mind at any rate, the principal constituent of the blood, that which gives it its characteristic color, are the red blood corpuscles, or, in technical language, erythrocytes. Yet this red color is not quite so characteristic as perhaps the layman supposes. Among the invertebrates the blood corpuscles may be colorless or colored, and in the latter case they may be green, red, yellow, blue, violet, purple, madder, mahogany, brown, lilac, etc. In certain organisms there are even found in the same blood a variety of different-colored corpuscles, such as yellow, green, brown, indigo blue and purple. The blood of the octopus is colorless in the venous condition, and blue in the arterial state.

But in all cases one of the principal functions of the blood, and in particular of the colored constituent of the blood, is the assimilation of oxygen from the air (or water in the case of aquatic animals), and the surrendering of such oxygen to the tissues during the course of the blood to the tissues. Thus, in the case of man, the red blood corpuscles absorb oxygen in the lungs, and acquire a bright red color, which they lose during their course through the body, as they give up their oxygen to the tissues, so that on its return to the lungs the (venous) blood is of a dark red color.

The study of the chemical and physical properties of the red blood corpuscle has revealed many remarkable facts. As regards their chemistry, the most significant point is that the red coloring matter of blood, so-called hemoglobin, has been found to be closely related to the green coloring matter, chlorophyl, of the higher plants. When we remember that the functions of these two bodies are closely related—hemoglobin serves to feed oxygen to the tissues, with the production of carbon dioxide, while chlorophyl operates in the opposite direction, assimilating carbon dioxide from the air, this looks like something more than an accidental circumstance. It seems in fact very probable that hemoglobin has been evolved from chlorophyl.



Amphiuma, which, of all animals, has the largest red blood corpuscles. They measure one three hundredth of an inch in diameter and are just visible to the naked eye.

The red color of human blood seems to be due to its iron content. The blue blood of octopus and many other invertebrates, on the other hand, seems to owe its color to the copper which it contains.

When we compare the proportion of blood to body-weight in different animals, we find a remarkable uniformity. Thus Prof. E. T. Reichert, in his classical memoir on "The Crystallography of Hemoglobins," from which most of the information here presented was gathered, gives the following figures:

	Proportion of Blood to Body Weight.
Man	1:13.1
Dog	1:13.5
Cat	1:15.1
Rabbit	1:18.1
Common mouse	1:31.1
Small birds	1:12.4
Lizard	1:20.4
Lamprey	1:19.4

Considering the wide range of species covered this is a remarkable set of figures. There are, however, some species in which the ratio is very different from the figures cited, the most extreme case noted being that of osseous fish, with a ratio of 1:63.

The proportion of red corpuscles to total blood varies somewhat for different species, as shown in the following table:

Man	48 per cent
Cat	43 "
Dog	42 "
Bullock	33 "
Horse	40 "
Fish	7 "

THE FORM AND NUMBER OF RED BLOOD CORPUSCLES IN RELATION TO BIOLOGICAL GENERA.

All the vertebrates are divisible primarily into two classes in accordance with the presence of non-nucleated or nucleated red corpuscles. Further divisions and subdivisions may be made through distinctions in the form, in the number per cubic millimeter, and in the sizes of these cells. In all warm-blooded animals except birds, the red blood corpuscles are non-nucleated, and they are circular, except in the Camelidæ (the class including the camel and the llama, for example) in which they are oval. In birds, reptiles, amphibians and fish, they are nucleated, and ellipitical or oval, except in the family of the lamprey and the seahorse, in which they are circular.

The mean diameter of the red blood corpuscles of different species varies within wide limits, the smallest corpuscles thus far examined being those of the musk-deer, which measure 2.1 microns, that is to say, thousandths of a millimeter, or something less than 1/10,000 of an inch; and the largest, those of the amphiuma, measuring 69.8 to 41.4 microns, or roughly 1/300 of an inch. These latter are in fact so large that they can be just discerned with the naked eye. Human red blood corpuscles have been more thoroughly studied than those of any other species. The extreme limits of measurements probably lie within four and ten microns, but the mean is about eight microns, or 1/3,000 of an inch.

In man the red blood corpuscles are remarkably uniform in size. It has been estimated that about 82 per cent are of average dimensions, 13 per cent larger and 5 per cent smaller.

While it is hardly possible to establish any general principle connecting the size of blood corpuscles with the

Blood crystals of the Chacma baboon.

α-Oxyhemoglobin of the Chacma baboon.

Blood crystals of the dog.

position of a given species in the scale of evolution, yet within closely related species, a gradation of this sort can be found. For instance, in the primates, there is seemingly an increase in the size of the corpuscles as the individual is higher in the scale of life. Thus the measurements are: chimpanzees, 7.4 microns; monkeys, 7.1 microns; lemur, 6.4 microns.

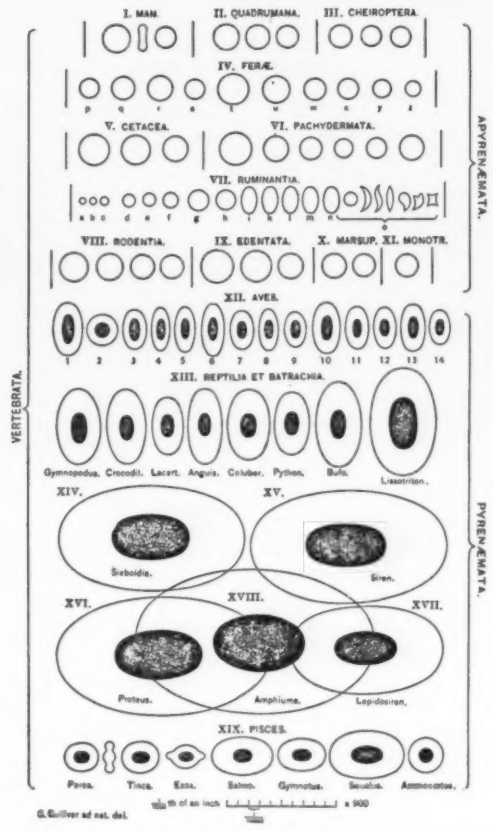
Unfortunately for the prosecution of criminals, the blood corpuscles of man do not differ very markedly from those of some of the lower animals. We shall see later how other tests have been evolved which furnish a reliable means of distinguishing between blood stains produced by human blood and stains produced from other sources.

THE NUMBER OF BLOOD CORPUSCLES AS A CHARACTERISTIC OF DIFFERENT BIOLOGICAL GENERA.

In the blood of all vertebrates the red blood corpuscles occur in inconceivable numbers. It has been estimated that the total number of cells in the human body is 26,500,000,000,000, and that of this number 22,500,000,000,000 are red blood corpuscles, in other words, over four fifths of the body cells are red blood corpuscles. The number of red blood corpuscles in mammals ranges from 3,500,000 to 18,000,000 per cubic millimeter; in birds, from 2,300,000 to 3,400,000; in fish, from 140,000 to 2,000,000. These are truly remarkable numbers. Think of this vast crowd of corpuscles, numbering in the case of man more than ten thousand times the population of the earth, hurrying through the channels of our system at such a rate that the majority of them have completed one entire circuit in the space of a few minutes! (It is estimated that a portion of the blood may complete the circuit in about one minute.) As compared with such a phenomenon as this, the traffic in the most congested thoroughfares of our great cities is mere child's play.

BLOOD CRYSTALS.

It has been known since 1840 that under suitable circumstances, the red coloring matter of the blood can be caused to crystallize. Since then the observations originally made by Hünefeld have been repeated by a number of later investigators. But the most modern and most



Gulliver's micrometry of red blood corpuscles, all drawn to a uniform scale.

complete investigation of the subject is recorded in a volume published by the Carnegie Institution of Washington in 1909, containing the report of a classical series of investigations, carried on by Prof. Edward Tyson Reichert, Professor of Physiology in the University of Pennsylvania, in conjunction with Prof. Amos P. Brown, Professor of Mineralogy and Geology in the same university. That a mineralogist should have been collaborator in this series of biological researches is not surprising when we remember that much of the work consisted in the examination and measurement of crystals. The method finally adopted by Reichert and Brown consisted in first of all adding oxalate to the blood to prevent its coagulation; then laking the product with ethyl ether, and centrifugalizing. The process had to be modified more or less according to circumstances. For instance, in many cases the blood employed was obtained from specimens forwarded from zoological gardens, and no longer quite fresh at the time of receipt. In such cases proper allowance had to be made for a certain putrefaction which had occurred in the blood.

We have had occasion to mention above the legal importance of blood test in criminal cases where blood stains

Blood crystals of the jackal.

are brought in evidence of guilt. But as was pointed out then, a test which relies merely upon the identification of the particular kind of blood corpuscles is very uncertain, owing to the fact that at the best, that is to say in their fresh condition, blood corpuscles from different sources are often difficult to identify, and other tests also are apt to be unsatisfactory. Now the work of Reichert and Brown has furnished a very highly refined means, by which it is possible to differentiate with great precision between the blood from different animals. A crystal is a body with perfectly definite properties, which can be measured accurately.

But while the application of blood crystallography to the prosecution of the criminal is of obvious practical importance, to the scientific man there can be no doubt that the supreme interest of the work of Reichert and Brown lies in the light which it sheds upon biological problems. Thus it is found that related species of animals display their family character by certain similarities in their blood crystals. This furnishes us with a test which we can apply in doubtful cases, and indeed, new as the method is, instances have occurred where a test thus applied has either brought to light an unexpected relationship, or else has settled a disputed point. Thus, for example, it has been found that the blood of the guinea fowl differs very considerably from that of the domestic fowl, to which this bird was supposed to be related. It is found on the contrary that the guinea fowl appears to be a close relative of the ostrich. Similarly, there has been considerable doubt as to the exact relationship of the bear as compared with certain animals, as the dog, the wolf, the fox, etc. The blood test has proved conclusively that the bear is closely related to the sea-lion and seal, rather than to the animals just mentioned, as indeed had been suspected by certain naturalists.

While even now the work of Reichert and Brown has borne remarkable fruits both for the criminal lawyer and for the biologist, we have every reason to expect that only a small part of the story has been told, and that much remains for future development.

Tidal Waters as a Source of Power*

An Estimate of the Commercial Feasibility of Exploiting Tidal Energy

By C. A. Battiscombe

THERE is little doubt that many attempts have been made to utilize the rise and fall of the tide as a source of power, other than those with which we are all familiar, but these attempts have not been crowned with conspicuous success. Of two such attempts, one at Havana was successful, and is said to be still doing useful work; another at Cowes (Isle of Wight) was a failure partly on account of the heavy charges for the wharves with which it interfered, but chiefly on account of the inconvenience arising from its quiescence during the tidal interval, since no workman could be induced to remain at the factory where the machinery, actuated by the tidal installation, worked only for two periods of two or three hours a day, at changing times; the irregularity of the hours causing the non-success of the enterprise.

While it is well within the range of possibility that electric accumulators may be improved to such an extent, from a commercial point of view, that they would suffice to maintain any required load over the tidal intervals, still it is impracticable to count on such a contingency at present. For this reason the author will confine his remarks to schemes designed to obviate the difficulty of the tidal interval. But he wishes it to be distinctly understood that he does not think that quiescence during the tidal interval would prove an insuperable objection to the utilization of the tides as a source of power, for purposes other than the generation of electricity for schemes in which the output must be continuous.

The sum of the tidal intervals at high and low water is practically a constant, but there is often a considerable difference between the length of the intervals at flood and ebb tide. At Havre, for instance, the interval at high tide lasts for two hours, and the variation of level in three hours is only about 13 inches.

For the purposes of this paper the duration of the tidal intervals may be measured from the turn of the tide to such time as the rise above low water, or fall below high water, would permit of turbines being actuated by the water entering into an empty, or issuing from a full reservoir in which the tidal water had been impounded.

The intervals between flood and ebb tide are variable in different places, and the rate at which the tide rises and falls at any given place depends on its position as well as on the range. Commencing shortly after the period of low water, the rise is gradually accelerated for two and a half hours, remains nearly constant for the next hour, and then varies at a decreasing rate until high tide level is attained. For purposes of illustration only, it may be said that, in the case of normal tides, one seventh of the total rise takes place in an hour and a half after low tide; five sevenths in the three following hours, and the remaining one seventh during the one hour and a half before high tide. Similarly, the fall of the tide proceeds in approximately the same manner. The point to be noted is that, speaking generally, the greater the rise and fall of the tide, the shorter the period that must elapse between high tide and the fall of the water to a definite number of feet below that level.

*Paper read before the Society of Engineers (London) and published in its *Journal*.

To take two extreme cases: The range of neap tides at Weymouth is 3¼ feet; in the Bay of Fundy, Nova Scotia, it is about 31¾ feet. Assuming that the tide must fall 1 foot 7½ inches before turbines can be operated from a reservoir filled to the level of high tide, a period of about three hours must pass before the water would fall to the required extent at Weymouth, while in the Bay of Fundy the period would not exceed 30 minutes.

To anyone who studies the rise and fall of the tides as a source of power it will at once be clear that the maximum range that can be counted on will be the minimum range of the tide. But to those who have not had the privilege of recording or examining tidal diagrams over an extended period, it may not be known that considerable difficulty may be experienced in ascertaining what is actually the least of low tides or the highest of high tides at any given part of the coast. At most of the important seaports tidal records have been made daily for several years, so that no difficulty need be experienced in verifying the constants given in the nautical almanacs, but where no records are available, continuous observations over an extended period will be necessary to establish the tidal constants. For most localities the tidal constants are recorded in the Admiralty Tide Tables, and as these are perfectly reliable, tidal observations may, to a large extent, be dispensed with. The height of neap tides on the coasts of the British Isles varies from 4½ feet off Dorsetshire to 31¾ feet off Portishead in the Bristol Channel. Generally speaking, the tidal range is low on the south coast between Bridport and Southampton, high on the southwest and southeast coasts. The average height of neap tides between Cape Cornwall and Swansea is 23 feet; between Portsmouth and Margate, 13 feet; and in the River Thames from North Foreland to London Bridge, 12½ feet.

As will be seen later, the head available for power purposes, where the output is to be continuous, may be assumed at one third of the range of minimum tides. As the head is the difference between water on the feed side of a turbine and the level of the delivery to the tail race, it follows that a turbine actuated by tidal water needs to be so arranged that the feed must, to be continuous, spring alternately from the tidal water and from a reservoir in which tidal water may be impounded. Since the power of turbines varies with the head and quantity of water available, and since the quantity of the tidal waters in this connection may be regarded as illimitable, it is evident that the power that could be developed from that source would depend on the quantity of water that can be impounded, that is, on the size of the reservoirs that can be formed to receive it. But it may be suggested that by taking advantage of the difference in time at which high tide occurs at different parts of the sea coast, it would be possible to eliminate the necessity of a reservoir by constructing twin installations in such situations that the tidal interval would be bridged and the continuity of the output assured.

The chief objections to such an arrangement are the greatly increased cost of maintenance due to duplicating the turbines and dynamos, increasing the length of the mains, and doubling the staff, and the necessity of damming the mouth of an estuary, making it valueless for the purposes of navigation. In such a humid atmosphere as obtains in England, too, the high voltage necessary for long-distance transmission would be impossible and the output from the central station would be so much diminished that the practical efficiency of the twin installations would be seriously impaired. In addition to this, the central or distributing station would need to be more or less equidistant from either generating station, and hence the location of manufacturing centers that could be supplied would probably be limited to the Midlands.

To return then to the matter of impounding the tidal waters in reservoirs, it is necessary, before proceeding, to outline the arrangement of turbines and reservoirs that the author believes to be practical and possible from an economic and commercial standpoint. Assuming for the moment that the turbines were placed in a chamber fitted with valves arranged so that the water might pass to them alternately from opposite directions, and that the tail race in like manner could be controlled by valves to permit the water to flow away in either direction alternately, it will be clear that if, by opening and closing one set of valves, water from a rising tide were free to flow from one side of the chamber through the turbines into a reservoir on the other side, by reversing all the valves when the tide had ebbed, water could be admitted to the turbines from the reservoir and would flow out into the tidal way.

But if the head is to be constantly maintained, more than one reservoir would be required; for, when the tide had risen to its full height and the reservoir at the end of the tidal interval had been filled to a level below high water, equal to the head required for the turbines, then the tide would have to fall to a level equal to twice that head before the turbines could again be operated by water impounded in the reservoir. Hence, to maintain a constant head, two or more reservoirs would be required.

Now, since the only expense of forming a reservoir, for which no artificial floor is required, is the cost of the outer walls, and since the height and thickness of those walls would need to be as great for a small as for a large reservoir, it follows that the cost of wall per cubic foot of water impounded would decrease nearly inversely as the capacity of the reservoir.

This being the case, it is manifest that the larger the reservoirs are made the less costly per unit of power will be their construction; and since more than one reservoir is required, it would, as a rule, be more economical to restrict the number by increasing the size as far as possible. It might happen that in a favorable position it would be possible to restrict the number of reservoirs to two, but under normal conditions it will be found that three are required.

The author has found that it is possible to vary the cycle of flow to and from the reservoirs in a number of different ways, but that the advantage gained by decreasing the area of the reservoirs through a complicated method of flow and delivery is more than compensated for by the simplicity of the arrangement that he has adopted. One of the methods alluded to is illustrated by the diagram Fig. 1. The method adopted by the author is shown by Figs. 2 and 3, reference to which is necessary for the clear comprehension of the following description.

The sequence of supply to and flow from the turbines may be described in the following manner:

Commencing at the turn of the ebb tide, sluice gates in the outer wall of reservoir *A* are opened, allowing all the water remaining in it to escape into the tidal way; at the same time valves in the wall of the supply chamber are opened to allow the water impounded in reservoir *C*, the level of which is that of the last high water, to discharge through the turbines for a period of about 2¼ hours.

When the contents of reservoir *A* have been discharged into the tidal way, the sluice gates are closed. The tide having risen one third of its range, the valves from reservoir *C* are closed, and other valves in the outer wall of the supply chamber are adjusted to allow the tidal water to become the source of supply to the turbines for a period of three hours and twenty minutes, during the whole of which time the water flowing from the turbines passes to reservoir *A* through valves in the side of the supply chamber. When the above-mentioned period of three hours and twenty minutes has elapsed, the tide will have risen to its full height, and the valves permitting the tail race to pass to reservoir *A* are then closed, while those giving access to reservoir *B* are opened.

In the outside wall of reservoir *C* a series of gate valves is provided, which allow the tidal water to flow into that reservoir and fill it up again to high tide level. Directly after the flow from the turbines has been diverted to reservoir *B* the sluice valves in the outside wall of reservoir *A*, referred to above, are again opened to permit of that reservoir being filled up to tide level, after which they are again closed. The tidal water continues to flow through the turbines into reservoir *B* for a period of about 2¾ hours, until it has fallen to one third of its range, when the valves admitting water to that reservoir and from the tidal way are closed, while those in the wall of the supply chamber from reservoir *A* and those permitting the tail race to pass out into the tidal way are opened, and remain open until, after a period of 4¼ hours, the tide has ebbed.

In the outside wall of reservoir *B* a hinged gate valve is provided, which permits of the contents of the reservoir being discharged into the tidal way, so that it will be empty when the tide has completely ebbed.

By referring to Fig. 2 it will be found that the working head from reservoirs *B* and *C* varies from the full range of the tide to one third of that range, and since the power of the turbines is dependent on the product of the head of water and its quantity it is evident that with an increased head fewer turbines will be required to maintain the peak load, and that the area of reservoirs *B* and *C* may be less than would be necessary if a uniform minimum head were maintained.

It will be seen from the above description and from the diagrams, that to obtain a continuous output of power by this method a very heavy expenditure is involved. Three large reservoirs must be constructed, and a supply chamber connected by valves both to the tidal way and to the three reservoirs; and the necessary valves, with electric apparatus to operate them from the power house, and a series of hinged gate or flap valves in the outside walls of the reservoirs, must all be provided.

It will also be recognized that the problem of utilizing the rise and fall of the tide for power purposes offers few engineering difficulties, so far as the principles are concerned, but that its practical solution depends on the choice of the site and on the economy of construction, or, in other words, on the design of the details. The real difficulty lies in the question of cost, of how to provide the necessary structural work without crippling the enterp.ise by excessive expenditure of capital.

The author has gone very closely into the probable cost of about four tidal installations, and has submitted his estimates to friends, accustomed to the consideration of such estimates from a financial point of view, and has uniformly been told that they are sound and that the interest on the capital expenditure would be sufficient to justify the outlay They made one reservation, however, that their knowledge of financial matters evidently warranted, namely, that such an undertaking would not attract capital unless its financial supporters could see their way to making 100 per cent at least on their own outlay. From the financiers' point of view, no doubt, this is a reasonable demand, but it is hardly one which would appeal to the ordinary investor, who would generally be content with 7 per cent interest on his capital if he could get it on a perfectly sound investment. Be this as it may, from the engineer's point of view the question of justifiable capital expenditure on commercial works, which he recommends, is limited to four points:

(*a*) That the works are necessary to the fulfilment of a known requirement.

(*b*) That they will be of a character sufficiently permanent to fulfil the purpose for which they are designed.

(*c*) That the advantage accruing from the provision of the works may be sufficient to justify a sinking fund large enough to amount to the value of the capital expended at the end of a period not exceeding 50 years in the case of a permanent structure.

(*d*) That the income to be derived from the undertaking will be sufficient to pay a reasonable amount of interest on the capital expended after deducting all annual expenses and charges.

If an engineer is able to make reasonably sure that these requirements will be fulfilled by his designs, then he is justified in recommending the expenditure of the capital required for the construction of the works.

Now, the author has found that to make a close estimate of the cost of so vast an undertaking as that under consideration, detail surveys are absolutely necessary, and continuous tidal observations are desirable, while a knowledge of the vested interests likely to be affected in the neighborhood of the installation, is essential. To make such a comprehensive investigation not only would it be necessary to spend a considerable amount of money, but at least twelve months would be required for its completion. Not being in a position to afford either the time or money for such investigations, he has been forced to content himself with rough estimates, allowing a very wide margin for contingencies, but otherwise, so far as is possible, based on actual designs for the structural parts of the work and on covering estimates for the valves, turbines and electric equipment, based on quotations from two or three firms of high repute. As an additional safeguard he has made no allowance for the reduced height of the walls of reservoir *C*, but has estimated the cost of the walls as though the section were uniform over the entire length at a maximum depth. This he has done to avoid the risk of under-estimation, as the cost of these walls seems to be the determining factor of the problem.

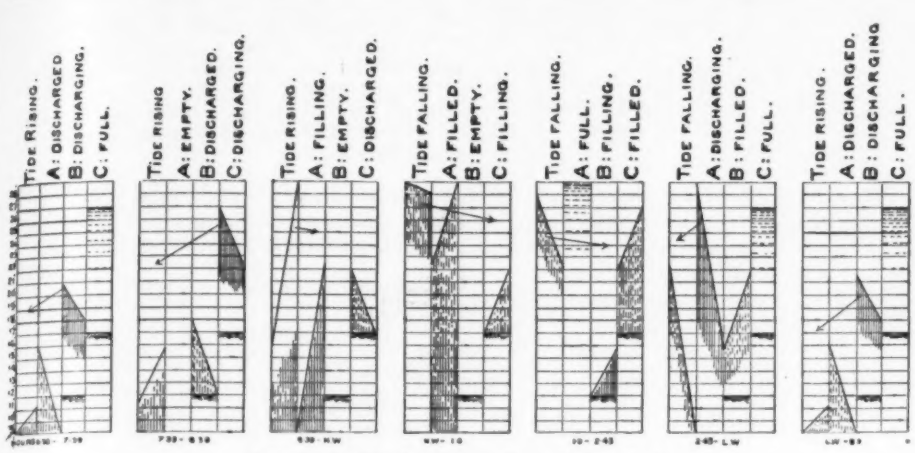


Fig. 1.—Feed to turbines—alternative method

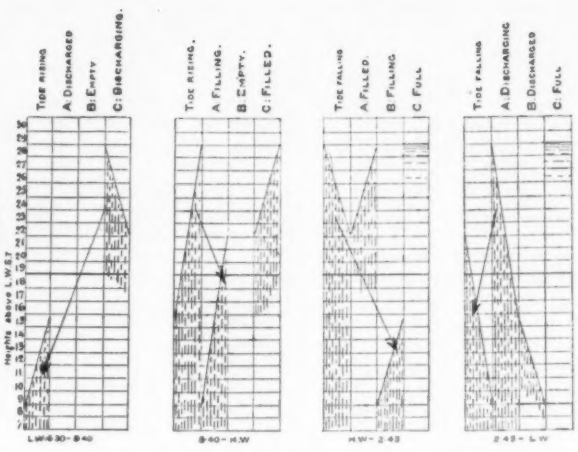


Fig. 2.—Feed to turbines—method advocated.

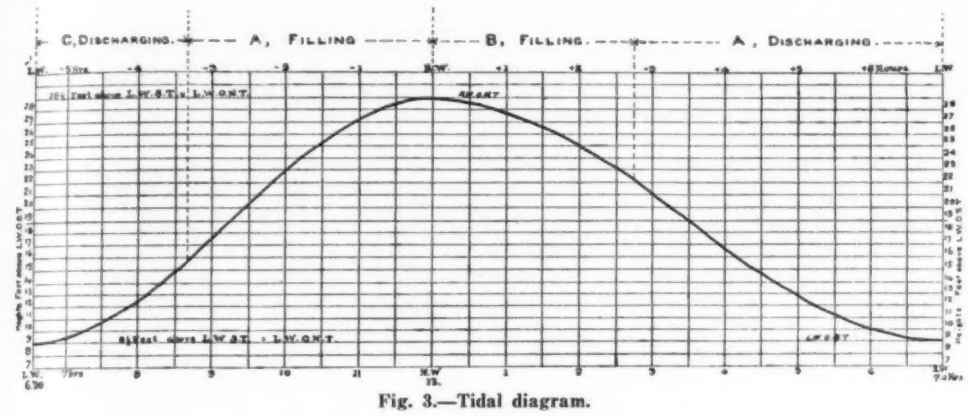


Fig. 3.—Tidal diagram.

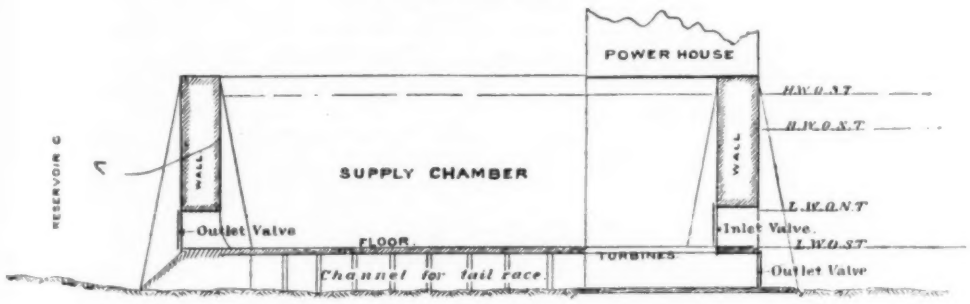


Fig. 4.—Diagram of section of supply chamber

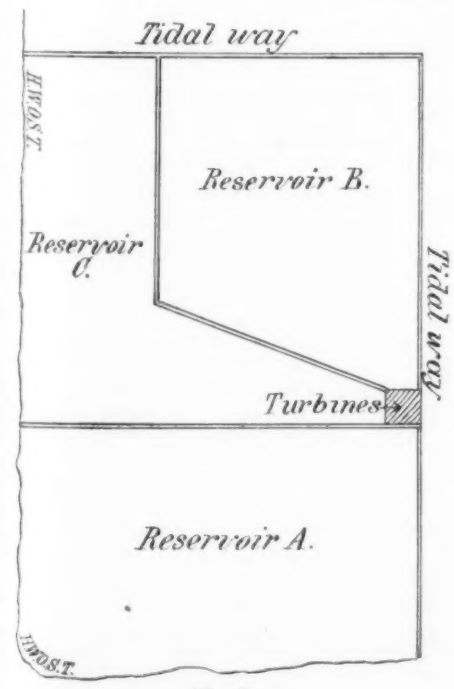


Fig. 5.

The system he has adopted in the design of the walls is a modification of that which will probably be more generally adopted within the next few years than has hitherto been the case, viz., trestles of ferro-concrete. The arrangement proposed in this case is that of ferro-concrete trestles, each weighing between 20 and 30 tons, having the outside posts grooved for the reception of slags weighing from 10 to 15 tons apiece.

The edges of the slabs are formed with a rounded V groove on the bottom and a similar rounded V projection on the upper edge; the joint between them is made either with neat cement plastered in the groove before the slab is lowered into position, or with a stocking bag filled with neat liquid cement, in which case the slabs would be grooved top and bottom. The joint between the trestle post and the end of the slab is made with neat liquid cement.

The trestles are deposited in position by means of a crane in a trench previously excavated or dredged for their reception; the slabs are next placed in position and grouted in, and then, when two or three bays are ready, the space between the two slab walls is filled in with earthwork, the top of which is protected with a layer of concrete about 7 inches thick, and lightly reinforced with expanded metal. This layer of concrete is intended to serve the double purpose of protecting the surface of the filling and of binding the tops of the trestles together, so that when complete the sides and top of the earthwork core will be completely inclosed and protected by a skin of ferro-concrete. The cost of a wall or faced embankment formed in this manner has been exhaustively considered, and has been found to work out at $6.80, $1.25 per yard run, with a height of 50 feet from the foundation to the top, inclusive of the cost of setting. The earthwork filling may be of sand or other convenient material, which could, as a rule, be obtained from the inner side of the embankment wall by means of a grab, and as the consolidation will be satisfactorily effected by the action of the tidal water, it has been estimated at a rate of 50 cents per cubic yard in the price given for the finished wall.

It has before been pointed out that the cost of the installation will vary nearly inversely as the capacity of the reservoirs, but though this is true in the case of installations for which the site has been selected, it is not true when applied to the comparative dimensions of two or more installations where the tidal range differs. Since the minimum head of water for the turbines is determined by the minimum range of the tide, and since, as the minimum range of tide increases, the maximum range increases more, it is evident that with an increase of the minimum head there will be a much greater increase in the height of the requisite embankment or reservoir walls. Hence, it is clear that the greater the minimum range of tide available, the greater must be the power capacity[1] of the completed installation to cover the cost of construction. As a matter of convenience a formula based on the tidal range may be used for getting an approximate idea of the output in horse-power for any particular location. Such a formula may be used as for preliminary investigations, and the subsequent investigations by trial and error can be much simplified by its assistance. The author suggests the following empirical formula for the purpose:

Let S = the range of spring tides in feet.
" N = the range of neap tides in feet.
" P = the minimum economical horse-power of installation.

Then $P = S + N \times 400$.

This seems to give a fairly close approximation to the minimum economical horse-power required for any particular ranges of tide, but it must not be forgotten that the local peculiarities of the site will be the determining factor, and that though it is better to get some idea as to the minimum size of the installation at the outset, it is essential that the figure so obtained should be regarded as falling within certain limiting values that can only be determined by exhaustive investigation.

In the case the author has selected for purposes of illustration the site is in the Bristol Channel, a site where the range of neap tides is 20 feet and of spring tides 38½ feet.

Using the formula given above:

$P = 400\ (20 + 38\frac{1}{2}) = 23{,}400$ horse-power.

But as it is desirable to take the worst case, the author has based his estimates on an installation of a total capacity of only 20,000 horse-power for neap tides.

For reservoir *A* (see the diagram Fig. 5,) the efficiency of the turbines has been assumed to be 77.5 per cent, as the head will vary very slightly, but in that of reservoirs *B* and *C*, where the working head will vary considerably, the efficiency has been assumed to be 75 per cent. The detail calculations of the several areas of the reservoirs and valves, being of a purely elementary character and taking up a considerable amount of space, have been omitted; the results can be easily verified.

The area required for reservoir *A* with a minimum working head of 6 feet 8 inches will be equal to the quantity of water required for the turbines per minute, multiplied by the time occupied in discharging 1 foot in depth of its contents during the longest period in which it serves the turbines, namely, 4 hours 25 minutes (see Fig. 3), or, say, 1,996,000 cubic feet minutes × 20 minutes = 39,920,000 square feet.

Similarly the area of reservoir *B*, with a mean working head of 12 feet, will be 28,359,367 square feet, and of reservoir *C*, with the same working head, the area will be 23,203,118 square feet.

The area of the valves giving access to and delivery from the supply chamber must be sufficient

[1] For the purposes of this paper it has been assumed that the electricity will be supplied in bulk, and hence the value of the load factor has been estimated to be very high. See estimate of demand;

to permit of the maximum flow of water passing through them at a maximum velocity of 5 feet per second. Hence, since the maximum quantity is found to be 1,996,000 cubic feet minutes, the area of each set of valves in the walls of the supply chamber must be 6,653 square feet. Of these valves six sets will be required, two of which are required for the passage of water to and from the tide; two for the passage of water to and from reservoir *A*; one to give access to reservoir *B*, and one for the delivery from reservoir *C*.

In addition to these valves there will need to be sluice valves in the walls of the three reservoirs to permit of the escape into the tidal way from *A* and *B*, of the water remaining impounded after the minimum head is lost and to give access from the tide to reservoir *C*. The area required for these valves will severally be: 12,293 square feet in the outer wall of reservoir *A*; 1,948 square feet in that of reservoir *B*; 2,125 square feet in that of reservoir *C*.

The area of the supply chamber is defined by the length of the walls required for the valves, and in the case under consideration works out to 490,000 square feet.

Since the area of the supply chamber is also that of the channel provided for the water flowing to and from the turbines, either to the reservoirs or to the tidal way, it is necessary to double it by a horizontal partition or floor, beneath which the tail race may pass, the feed water to the turbines being free to travel over it This floor may be constructed quite economically by forming it of square concrete slabs, lightly reinforced and supported at the corners by ferro-concrete piles, the joints between the slabs being made in neat Portland cement. The level of the surface of the floor will coincide with that of low water level of ordinary spring tides. A sketch diagram of the section of the supply chamber is given in Fig. 4.

The rough estimate for a tidal installation based on hypothetical data as regards many of the items must of necessity be very loose. The question of land is difficult, but it has been assumed that all that will have to be purchased is a strip one chain wide extending over the whole land face of the installation above the high water line of ordinary spring tides.

Two methods are commonly practised for raising capital for an enterprise of this nature. In one the capital is raised by subscription from investors; in the other by raising a loan to be repaid with interest in a predetermined number of equal instalments. The latter method is that adopted in the case of municipal undertakings, which, though an extremely costly way of raising money, must be considered in this connection.

The cost of the Board of Trade unit of electricity depends on the annual charges that have to be met, as well as on the maintenance charges, so that the method of raising the necessary capital has an important bearing on the initiation of a costly enterprise such as that under consideration.

It is estimated that the annual and maintenance charges on the installation, exclusive o all charges for local sub-offices, sub-stations, etc., will be as follows:

Wages, salaries and stores	$28,945
DEPRECIATION:	
Motors and electric apparatus, 10 per cent	22,930
Turbines and accessories, 5 per cent	15,000
Electric cables, 3 per cent	13,000
Valves, 5 per cent	3,815
Total	$83,690

To this must be added the annual investment of equal amounts as a sinking fund, or insurance charge, which in the case of the capital being raised by private subscription, may be assumed to accumulate at the rate of 3½ per cent per annum.

On this assumption, and limiting the period of this annual charge to 50 years, a sum of $36,260.75 must be set aside annually to secure at the end of that period an amount of $4,750,000, the capital required for the construction and equipment of the works.

Adding this amount to the annual charges for the items specified above, namely	$83,690
Sinking fund	36,265
The total annual charges amount to	$119,955

or in round figures, $120,000.

Leaving for the moment the question of annual charges, those relative to the possible supply and demand have next to be considered, that is, the capacity of the installation relatively to the demand for electricity. (See footnote, page 127.)

ESTIMATE FOR A HYDRO-ELECTRIC INSTALLATION OF 20,000 HORSE-POWER, WHERE THE RANGE OF NEAP TIDES IS 20 FEET AND OF SPRING TIDES 38 FEET 6 INCHES.

Description.	Quantity Unit.	Rate.	Cost.	
Legal and professional			$100,000	
Land			52,500	$152,500
Reservoir walls	12,203 yd. lin	$171.25	2,089,765	
Walls of supply chamber	933 yd. lin	475.00	443,175	
Floor of do., including all labor	46,667 sq. yd	9.00	420,005	
Walls at valve openings	571 yd. lin	465.00	265,515	
Power-house, foundations	1,000 sq. yd	25.00	25,000	
Power-house, superstructure	600,000 cu. ft.	.14	87,500	
Valves to supply chamber and walls of reservoir *A*	52,210 sq. ft.	5.00	261,050	
Valves, walls of reservoir *B* and *C*	4,073 sq. ft.	3.75	15,275	
Contingencies, 10 per cent			360,730	3,968,015
Valve-motors, etc.			50,000	
Turbines and accessories			300,000	
Dynamos and electric equipment			179,300	
Electric cables			100,000	
				629,300
		Total, say	..	$4,750,000

The general question of the demand for electricity will be referred to in the concluding remarks, but at this point it is necessary to make some reasonable assumption as to the demand that might be expected under the existing conditions of the market, and by taking a percentage of that maximum demand, to arrive at that which could be reasonably counted on.

Of the 365 days in the year there will be 52 or 53 Sundays, the same number of Saturdays, and about 7 holidays.

Assuming that the demand in 24 hours of working days will be equivalent to a peak load of 15 hours, and that the demand on Saturdays will be one half, and on Sundays and holidays one third of this amount; then the number of hours per annum in which the demand would be equivalent to the assumed maximum peak load will be:

259	days at	15 hours	3,885 hours
53	"	7½ "	397 "
60	"	5 "	300 "
Total			4,582 "

The capacity of the installation is 20,000 horse-power, or nominally 14,920 kilowatts, but as there will be a certain amount of leakage or loss of electricity on the mains, 25 per cent must be deducted from this figure, so that the effective capacity of the installation must not be considered to exceed 11,190 kilowatts.

But it has been estimated that the maximum demand will not equal the total capacity of the installation for more than 4,582 hours per annum, that is:

11,190 kilowatts × 4,582 hours = 51,272,580 Board of Trade units per annum.

Hence, the supply being fixed by the maximum demand, the cost of one Board of Trade unit would be equal to the amount of the annual charges divided by the annual output in those units.

It has been estimated that if the required capital were raised by private subscription, the total annual charges would amount to $120,000, so the cost of one Board of Trade unit would be:

$$\frac{\$120,000}{256,362,900} = 0.2177 \text{ of a cent.}$$

Again, assuming that the actual demand would fall short of that which has been taken as a maximum by 20 per cent, then the cost per Board of Trade unit would be 0.2177 cents × 1.25 = 0.2720 cents.

This cost represents an annual expenditure of $120,000, or $12.63 per cent per annum on the capital outlay.

Hence, to make a clear profit of 7½ per cent it would be necessary to fix the minimum selling price at 1.0475 cents.

Even supposing that the capital expenditure has been slightly under-estimated, still these figures are sufficient to show that if the selling price per Board of Trade unit were fixed, say, at a mean price of 1.562 cents, there is strong presumptive evidence in favor of the success of the undertaking from the investor's point of view.

But if the undertaking is regarded as a municipal enterprise, the necessary capital would be obtained by means of a loan that must be repaid by annual instalments of the interest on the whole amount, plus that amount which, accumulating a compound interest at a predetermined rate, would at the end of a definite period amount to the sum originally lent.

In the case under consideration this period may be fixed at 50 years. The various annual charges would then be:

REPAYMENT OF LOAN.

Say, 4½ per cent on $4,750,000		$213,750
Annual repayment (on a basis of 4½ per cent for 50 years)	26,615	
		$240,365
Maintenance charges, etc.		83,690
Total annual charges		$324,055

The cost per Board of Trade unit would, in this case be:

$$\frac{\$324,055}{\$256,362,900} \times 1.25 = 0.7915 \text{ of a cent nearly.}$$

In this case, too, if the selling price per Board of Trade unit were to be fixed at 1.0415 cents there would be no risk of loss.

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